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A multiple micro-pulse generator

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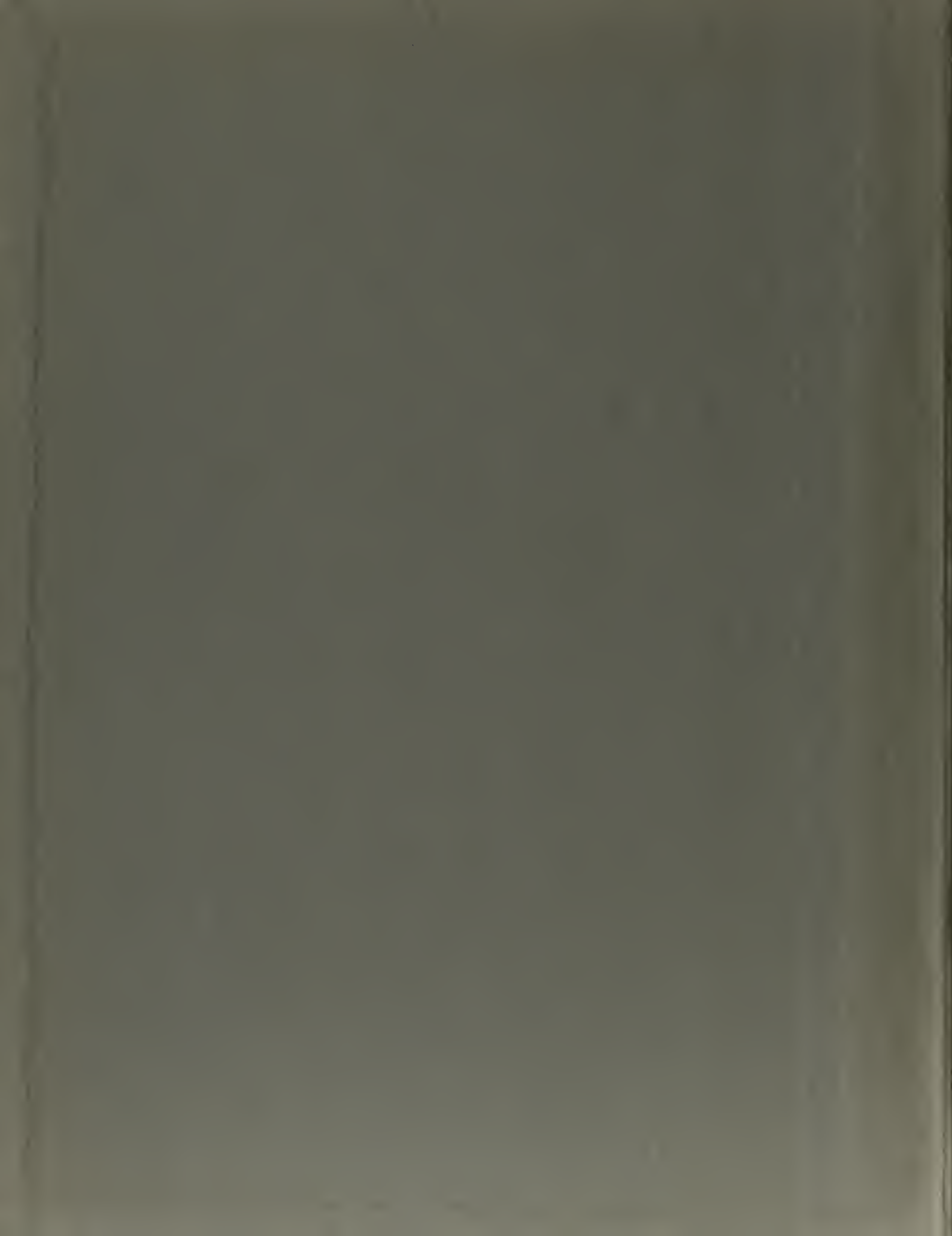
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A MULTIPLE MICRO-PULSE
GENERATOR

John W. Rhinesmith





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A MULTIPLE PICTURE-PULSE GENERATOR

JOHN W. RHINESMITH

By:

Lt. John W. Rhinesmith, USN
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FOREWORD

This report describes in some detail the work performed by the author during a thirteen week period extending from 2 January 1952 to about 29 March 1952. It is submitted in partial fulfillment of the requirements of the Engineering Electronics course at the U. S. Naval Postgraduate School, Monterey, California.

The experimentation was carried out at Melpar, Inc. in Alexandria, Virginia.

The report is in a summary format rather than a chronological one. It includes considerable engineering and product detail in order to assist those who may use the unit built, or who may undertake construction of similar units in the future at Melpar.

In the laboratories of this firm there was, at this time, the need for a multiple pulse generator for use in the general development of pulse time modulated equipments. In the course of design of these pulse time modulated equipments, testing was involved which required short S-band r-f pulses. A TS-155C r-f signal generator was modified to furnish these test signals. The TS-155C signal generator itself, however, had to be modulated by a series of very narrow pulses with rise times of the order of a tenth of a microsecond. These pulses were required to be capable of being positioned, in time, as close together as six-tenths of a microsecond, and furthermore they were to be capable, either singly or severally, of being wobbled at audio frequencies (20 to 3000 cycles per second) up to 1.0 microsecond either side of their normal positions.

This report is submitted to you in accordance with the provisions of the Act of March 3, 1879, relating to the publication of the reports of the several departments of the Government. It contains a general statement of the work of the Department of the Interior during the year 1899, and is divided into two parts, the first of which contains a general statement of the work of the Department, and the second of which contains a statement of the work of the several bureaus and offices of the Department.

The Department of the Interior is one of the most important of the Executive Departments of the Government, and its work is of the highest importance. It is charged with the management of the public lands, the regulation of the Indian affairs, the supervision of the mining industry, and the management of the National Forests. It is also charged with the management of the National Game Preserve, and the management of the National Monument.

The Department of the Interior is organized into several bureaus and offices, each of which is charged with a specific function. The Bureau of Land Management is charged with the management of the public lands, and the Bureau of Indian Affairs is charged with the management of the Indian affairs. The Bureau of Mining is charged with the supervision of the mining industry, and the Bureau of National Forests is charged with the management of the National Forests.

The Department of the Interior is also charged with the management of the National Game Preserve, and the management of the National Monument. The National Game Preserve is a large area of land in the State of Montana, and the National Monument is a large area of land in the State of Colorado.

The Department of the Interior is one of the most important of the Executive Departments of the Government, and its work is of the highest importance. It is charged with the management of the public lands, the regulation of the Indian affairs, the supervision of the mining industry, and the management of the National Forests. It is also charged with the management of the National Game Preserve, and the management of the National Monument.

The need for such a multiple pulse generator, or modulator, is the justification for the time and effort expended in its design and construction.

Every courtesy, facility, and encouragement was extended by those who were my associates at Melpar. For this I am extremely grateful.

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John D. Rockefeller

INTRODUCTION

The design and testing of the pulse time modulated units, mentioned in the foreword required a laboratory layout of considerable flexibility. Both the r-f signal generator and the multiple pulse generator used to modulate it had to meet rather severe requirements as reference to their outputs.

There were not available, commercially, any S-band r-f signal generators capable of being pulsed satisfactorily at such close intervals as the .6 microsecond spacing required. This presented the possibility of either modifying an r-f generator, such as the TS-155C, or of building a new unit employing a pulser tube and cavity that could be triggered at the required time intervals.

Another problem now appeared. This was the question of what to use as a modulator for the r-f generator referred to above. This modulator or pulse generator had to meet the following needs:

It must generate a train of at least five pulses.

These pulses must not be greater than .2 microsecond in width at their 50% amplitude points.

The rise time of an individual pulse must not exceed .1 microsecond.

The individual pulse must not contain a transient that will interfere with a following pulse, when spaced as closely as .6 microsecond (leading edge to leading edge).

The pulses must be of sufficient amplitude to fire the r-f generator which the unit is to modulate.

THE UNIVERSITY OF CHICAGO

The Board of Trustees of the University of Chicago, in its meeting of the 10th day of May, 1906, has resolved to accept of the offer of the University of Chicago Press to publish the works of the late Professor James H. Thompson, D.D., in the series of the University of Chicago Press, and to pay for the same the sum of \$10,000.

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Each pulse must be capable of being positioned or delayed over a period of at least 0 to 3 microseconds.

Any selected pulse or pulses must be capable of being modulated, in time, sinusoidally at a frequency of 20-3000 cycles per second, with an excursion up to 1.0 microsecond either side of the initial position.

Finally, there must be no cross talk between pulses in the output train.

To meet these requirements, the pulse generator or modulator described in this paper was evolved.

In order that the design and construction of this piece of test equipment might follow a logical and orderly sequence the unit was broken down into ten sections, or so called channels (see drawing EAl).

Channel (A) is a free running blocking oscillator with a control for adjusting the pulse repetition rate. The output pulses from this channel control channels (B) and (C).

Channel (B) is composed of a delay multivibrator and slave blocking oscillator. The output is a positive pulse which can be delayed by adjusting the recovery time of the delay multivibrator.

Channel (C) contains a delay multivibrator, a clipping and stretching pulse shaping network, an audio amplifier and a slave blocking oscillator. A fixed d-c potential, a positive pulse with a stretched leading edge, and an audio frequency sine wave are combined in the grid circuit of the slave blocking oscillator. This combination produces a varying bias which controls the time of firing of the blocking oscillator. The output of channel (C) is a positive going pulse which is wobulating at the same audio frequency as that audio signal on the grid.

The outputs of these two channels (B) and (C) are connected individually to the contacts of a bank of five single pole double throw switches. Each of these switches selects the pulse, fixed or wobulated, to be used to control a separate pulse generation channel, similar in circuitry to channel (B). These five channels are labeled (D) through (H).

As has been indicated, each of the channels (D) through (H) produces a single positive output pulse. This pulse is either stationary or wobulating depending on the pulse selected by the selector switch to control the channel.

The five pulses generated by these channels then are combined in the mixing channel (K). The output of this channel is either a positive or a negative pulse train which can be coded as explained above.

The remaining section, designated Channel J, is the regulated power supply.

A complete block diagram showing the individual stages within the channels is included as drawing EA2. In the following pages, a detailed description of the functions of the channels is given. The channels are treated individually. The description of the action in the final or mixing channel is quite extended and shows clearly that the output from this channel meets the pulse train requirements stated previously, and that the unit, when finally built and tested, constitutes a satisfactory source of pulses with the characteristics and requirements set forth earlier in this introduction.

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Detailed Description of Channels:

Channel A. FREE RUNNING BLOCKING OSCILLATOR

This channel is composed of a single stage, 65670, a high reliability, high frequency twin triode. Referring to drawing EA3, the triode is operated as a free running blocking oscillator, and is used as the master oscillator or timing reference for the entire unit.

The pulses produced by this stage are very narrow, about .2 microsecond, and their frequency can be controlled. R_5 , which is a 5 megohm potentiometer front panel control and C_5 , a 100 micromicrofarad capacitor, determine the pulse repetition frequency. R_{26} , a 5.1 K resistor, is for the purpose of limiting the small grid current which tends to flow just before the tube blocks. The damping resistor R_{24} , 2.7 K, is used in the grid circuit to limit, somewhat, the overshoot after blocking occurs.

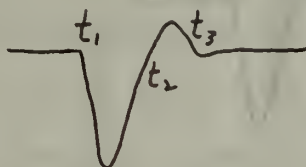


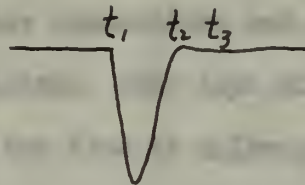
Plate waveform

Referring to the above sketch of the pulse waveform at the plate of the oscillator tube, the damping action is as follows:

Prior to t_1 the tube is in a cutoff state and the plate rides at B_+ , or about 260 volts positive. At t_1 , the grid has recovered sufficient to bring the tube out of cutoff and into the conduction region. The plate potential then drops and the grid potential rises very rapidly due to the regenerative action of the pulse transformer. During this period, t_1 to t_2 , the damping resistance, reflected into

the plate circuit as an impedance of the same value, due to the 1:1 turns ratio of the windings, is in parallel with the small dynamic plate resistance of the tube. The damping resistance then has only a small effect on the total swing of the plate and so attenuates the pulse amplitude only slightly.

During time t_2 to t_3 , however, the situation is considerably modified. At time t_2 the tube is cutoff and the positive swing, or first overshoot, of the plate waveform is developed across the static plate resistance of the tube. As was the case from t_1 to t_2 , this tube impedance, now very much larger than during conduction, is again shunted by the reflected impedance of the small damping resistor. Consequently, the amplitude of the positive swing is greatly reduced with the following output wave at the plate as a result.

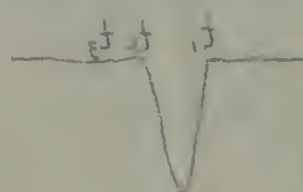


By thus reducing the transient to negligible proportions, the pulse repetition rate can be made very high with no cross talk between successive pulses.

The output of the stage is a narrow positive pulse developed across the 100 ohm cathode resistor, R_{25} . It is coupled thru crystals Y_1 and Y_2 , both Raytheon type CK703, to channels (B) and (C) respectively.

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An interesting feature of the stage is the blocking oscillator transformer. This transformer consists of twelve turns on the primary, and the same number on the secondary, of #38 SSE wire, wound on a mandrel of 3/16" outer diameter. Complete instructions are given on page 48 for winding these coils. The coils are completely contained in a small pot core, see the figure on page which is mounted on a 1-1/8" X 5/8" piece of 3/32" glass silicone board. The electrical properties of this silicone glass laminate are very much superior to those of other types of rigid laminations for electrical applications and, in addition, this type board is characterized by high heat stability and low water absorption. The coil leads are terminated on turret terminal lugs, type 1724C, made by the Cambridge Thermionic Corporation. The turret type lug has two soldering spaces, permitting two or more connections without superimposing wires and assures good contact with neater connections and appearance. The lugs are of brass, heavily silver plated. This type of mounting is a necessity since the #38 wire size is too fine to allow good point to point soldering. The damping resistor is connected between the turret lugs, on which leads F1 and S1 are terminated, affording a sturdy mounting.

The Ferroxcube core employed is made from manganese zinc ferrites, pressed into shape and sintered to give considerable hardness to the element. The material is characterized by high initial permeability, low total losses (residual, eddy current, and hysteresis), high saturation flux density, and good temperature stability. The initial permeability is more than 15 times that of presently available powdered iron cores.

[illegible]

Above 15 kc the hysteresis losses in a core are negligible in comparison with the eddy current losses. The resistivity of ferroxcube material is so very high that these eddy current losses are very small and any need for laminating the core is eliminated.

The above properties together with the enclosing type core used constitute a very effective pulse transformer. The high Q and permeability permit using a small number of turns, which leads to a very narrow pulse. The waveforms for this stage are shown on page 51.

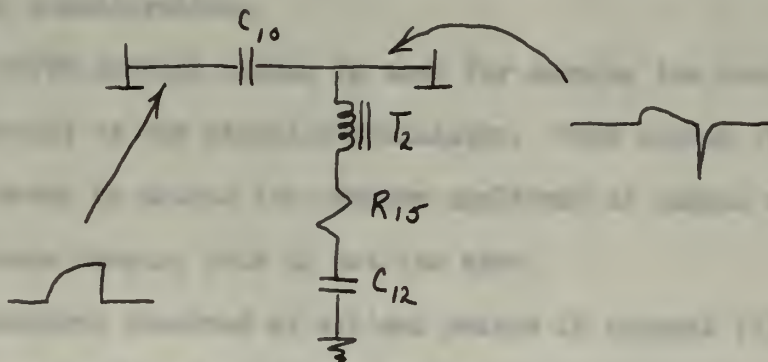
A sync output is also taken from this section. This is required when the stage is functioning at low pulse repetition rates. Under these conditions, after the tube has blocked, the grid potential approaches cutoff very gradually. As a result there is a considerable range, time wise, over which the tube might again conduct, any slight positive fluctuation in the recovering waveform, as cutoff is neared, being sufficient to cause the tube to again cycle. This results in a very small jitter which can only be overcome by using some means of syncing, such as a sine wave superimposed on the grid, to cause positive firing. However, since the sync output is used to "time control" the rf signal generator which this test unit modulates, the slight jitter effect is not apparent in the pulsed output of that generator.

Channel B. DELAY MULTIVIBRATOR & SLAVE BLOCKING OSCILLATOR

This channel generates a positive pulse which can be delayed over a range of several microseconds. Three stages are included in this channel, V_9 and V_{10} the two halves of a 6J6, constituting a one-shot delay multivibrator and V_{11} , a 6C4, a slave blocking oscillator. Referring to figure EA4, action of the circuit is as follows:

A positive pulse from channel (A) is coupled through C_8 to the grid of V_9 . The fixed bias on this grid is such that this positive pulse is sufficient to cause V_9 to conduct. The action that follows is that of a typical one shot multivibrator. The output at the plate of V_{10} is a positive square wave. This wave is not coupled back thru C_7 and C_8 to the cathode of V_{13} because of the unidirectional nature of the crystal, Y_1 , and hence does not interfere with the proper operation of channel (C). The width of this square positive pulse is variable and is controlled by potentiometer R_{30} , a front panel control, in the grid circuit of V_{10} .

The RLC network composed of C_{10} , the plate coil of T_2 , R_{35} and C_{12} differentiates this positive square wave as shown in the accompanying schematic.

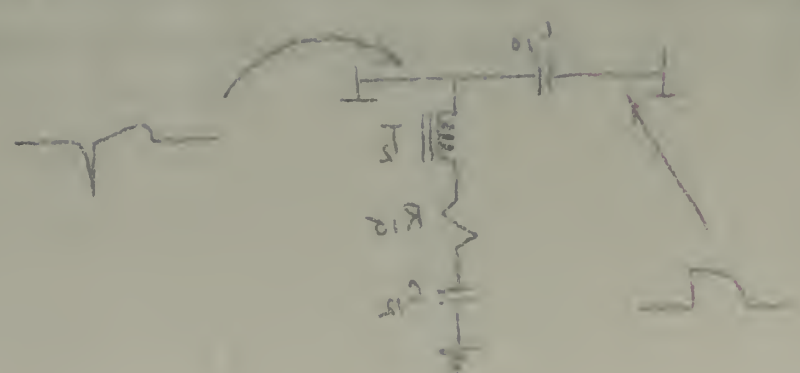


General 6. Small capacitance & large voltage output

This circuit consists of a common emitter stage with a load resistor R_L and a bypass capacitor C_E . The input signal is applied to the base through a coupling capacitor C_C . The output is taken from the collector through a coupling capacitor C_C . The circuit is biased by a base resistor R_B and a collector resistor R_C . The load resistor R_L is connected in parallel with R_C . The bypass capacitor C_E is connected in parallel with R_E . The circuit is shown in Figure 6.

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The negative spike (the differentiated after edge of the square pulse) serves to initiate action in stage V_{11} , the slave blocking oscillator. This tube is normally held in a non-conducting state by a fixed bias of about -27 volts on its grid. The output of this blocking oscillator is a positive pulse developed across R_{34} , 220 ohm. It is coupled out through a .01 capacitor to C_{13} and may be used to control pulse generation channels (D) through (H).

C_6 , C_{12} , and C_{14} all serve as decoupling capacitors and so prevent modulation of either the B plus or the bias supplies. R_{32} , R_{28} , and R_{29} comprise a voltage divider network from plus 260 volts to minus 42 volts, providing a fixed bias of about -20 volts on the grid of V_9 under dynamic conditions. This keeps the tube well below cutoff and precludes the possibility of the multivibrator free running. This possibility of free running must be avoided since V_{11} will conduct very heavily in the event it occurs. R_{35} is a 1 watt resistor and will burn out quickly when so heavily overloaded. Under normal operation the duty factor is very small since V_{11} conducts only a fraction of a percent of the total time of a cycle and overdissipation in V_{11} and R_{35} is not then a factor for consideration.

Y_3 , a CK708 crystal diode, is used for damping the overshoot in the grid circuit of the blocking oscillator. This method of damping is used in order to obtain the maximum amplitude of output signal. With resistance damping this is not the case.

The waveforms observed at salient points in channel (B) are shown on page 52. Attention is called to that waveform observed at the plate of V_9 . The dotted line, $t_2 - t_3$, shows the expected wave form, the

Channel C. DELAY MULTIVIBRATOR, STRETCHING & SHAPING NETWORK, SLAVE
BLOCKING OSCILLATOR & AUDIO AMPLIFIER

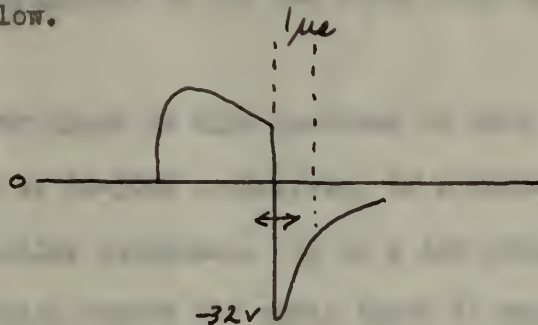
This channel, shown schematically on drawing EA5, produces a pulse about .2 microseconds wide which can be positioned in time over several microseconds and which can be wobbled timewise about one-half microsecond either side of its unmodulated position. The wobulation can be carried out over a frequency range of a few cycles up to several thousand cycles. Over this frequency range and excursion in time the modulation is essentially linear and has no discontinuities. This output pulse is used in the same manner as that from channel (B), to control pulse generation channels (D) through (H).

The entire channel (C) is made up of seven stages. V_1 , and V_2 constitute a variable delay one-shot multivibrator. V_3 is a diode connected triode, 15670, used for clipping. R_{38} , C_{23} , R_{46} , and R_{49} constitute a pulse stretching and shaping (integrating and peaking) network. V_4 is an inverter - amplifier which is followed by V_5 , an isolation stage cathode follower in which the leading edge of the pulse is further stretched. V_6 is an audio amplifier with low frequency compensation to improve the response of the stage. V_7 is a slave blocking oscillator, normally biased below cutoff, controlled by the combined signals from V_5 and V_6 on its grid.

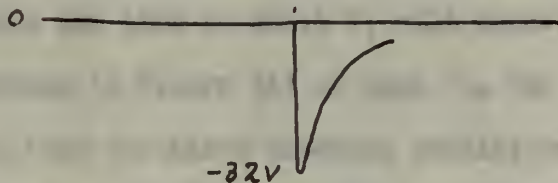
The complete operation of the channel is as follows:

A positive pulse about .2 microseconds wide and 45 volts in amplitude is coupled from channel (A) through C_{15} to the grid of V_1 , the normally OFF section of the delay multivibrator. R_{43} , R_{40} , and R_{39} comprise a voltage divider network which biases V_1 below cutoff with about -30 volts on the grid. The output of the delay multivibrator is

a positive square wave at the plate of V_2 , and the width (position of the trailing edge) of this pulse is controllable by varying R_2 , a 500K potentiometer front panel control. This square wave is differentiated across the $C_{22} - R_{48}$ combination. The diode V_3 passes only the negative pulse obtained from the differentiation of the trailing edge of the square wave. The differentiated pulse as appearing at the cathode of V_3 is shown below.



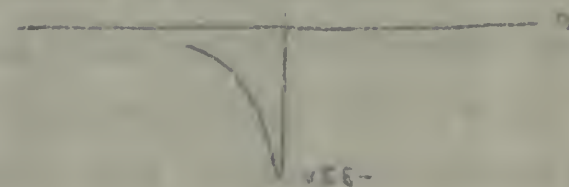
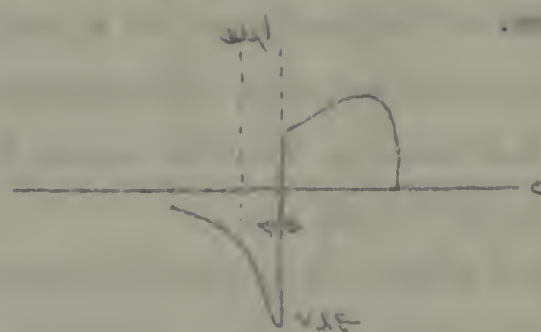
The clipped waveform on the plate of the diode is



The pulse is stretched from .2 microsecond to .4 microsecond by the charging of C_{23} , the stray or shunt capacitance from pin 3 of V_3 to ground. This leading edge is now the important factor for consideration. The negative pulse is developed across the $R_{146} - R_{49}$ combination and a portion of it impressed on the grid of V_4 . In this stage it is inverted and amplified and the leading edge of the plate waveform is stretched to about three microseconds. With a rise time of this duration the early portion is nearly linear. The integrated

It is important to note that the results of this study are not generalizable to all populations. The study was conducted in a specific population and the results may not be applicable to other populations. Therefore, further research is needed to confirm the findings of this study in other populations.

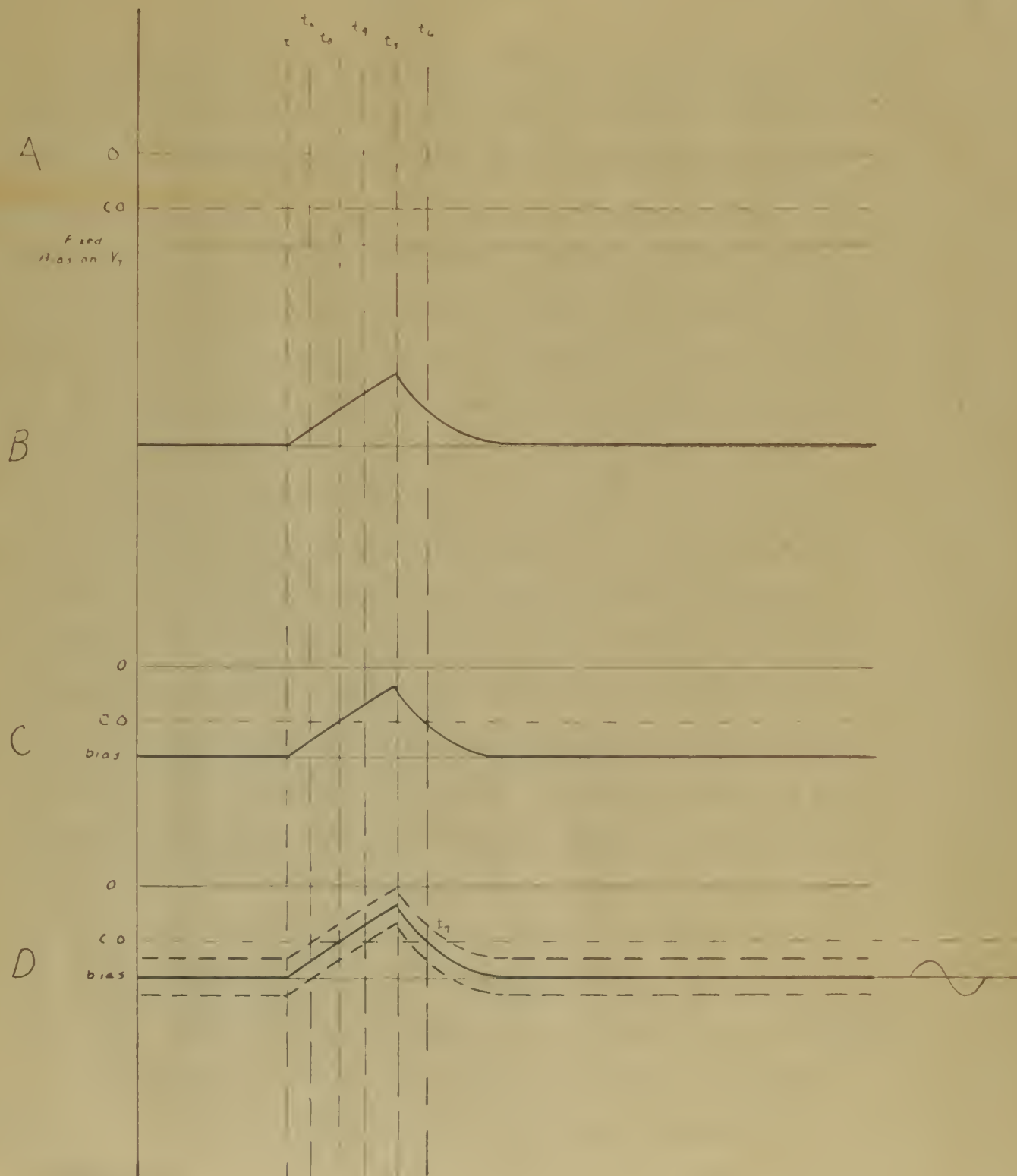
Source: *U.S. Census Bureau, 1990*. The distribution of income is presented in the appendix at the end of the report.



wave is coupled via C_{24} to the grid of the cathode follower V_5 . In the cathode follower stage the pulse is further stretched (integrated), a characteristic of such stages. The three microseconds rise time of the pulse on the cathode of V_5 is nearly uniform in its rate of rise. The positive pulse at the cathode of V_5 is coupled through capacitor C_{26} to the grid circuit of the slave blocking oscillator stage, V_7 . This waveform is superimposed on the d-c fixed bias on the control grid of this stage.

An audio input is also provided in this channel. The audio source, a sine wave of 20-3000 cycles/sec, is a Hewlett Packard 202D audio oscillator or similar equipment. V_6 is a low frequency compensated audio amplifier which boosts the audio input in amplitude, after which the signal is coupled through C_{27} to the grid circuit of the slave blocking oscillator. This sine wave form is then superimposed upon the dc fixed bias, also. The three signals (d-c bias, pulse, sine wave) then combine to determine the time at which V_7 will cycle.

Referring to figure (A) on page 15a, the static conditions are seen to be such that the slave blocking oscillator is biased below cutoff. In this state there is a zero output from the channel. Figure (B) shows the positive pulse with a sloping leading edge which is coupled through C_{26} to the grid circuit of V_7 from V_5 . This pulse combines with the dc bias to give the wave shape of figure (C). Now, it can be seen that at time t_3 the combined signals add to a value which pushes the potential on the grid out of cutoff. At this time, then, the tube conducts, blocks, and completes a cycle with a positive pulse about .2 microsecond wide being developed across R_{47} , the 100 ohm cathode resistor. This pulse and that at the grid are shown on page 53, Waveforms for Channel (C).



If only the fixed d-c bias of about -20 volts and the positive pulse from V5 were present in the grid circuit of V7, the tube would fire once each time the positive pulse arrive. The recovery time of the stage is sufficient to prevent another cycle being initiated in the time period of t_3 to t_6 when below cutoff conditions are not present. The recovery time actually is such that, at some later time t_7 , a cycle could occur if the grid potential were raised above the cutoff point.

The audio frequency sine wave injected into the grid circuit from the audio amplifier stage V6 modifies the times of firing indicated above. This wave, shown at the right in figure (D), has a frequency very much smaller than that of the positive pulse of figure (B). The d-c fixed bias can be considered to be slowly modulated, toward and away from the cutoff level, by this audio frequency signal. Referring to figure (D), left hand portion, the effect of this sine wave modulation is seen to be on the firing time for the tube V7. As the sine wave increased positively, the firing time is advanced from t_3 to t_2 (upper dotted waveform). When the sine wave swings to its negative extreme the firing time is delayed to time t_4 . Recalling that many positive pulses occur during a single sine wave, the firing time is seen to vary sinusoidally from t_3 to t_2 , back to t_3 , to t_4 , and back again to t_3 during a single audio cycle. The degree of linearity with which this variation of firing time occurs is a function of the uniformity of the slope, or rate of rise, of the leading edge of the positive pulse. Controls R3 (coarse) and R4 (fine) are used to adjust the fixed d-c bias so that firing occurs during the earlier, more linear, portion of the positive pulse's leading edge. Care must be

[illegible]

taken, however, that time t_3 , figure (C), is not advanced so much that t_2 , figure (D), would tend to occur before t_1 . Under such conditions the oscillator would free run and no control would be exercised over the stage during this t_2 to t_1 , period.

The slave blocking oscillator itself is conventional and nearly identical with the one in channel (B). The positive, wobbled, output pulse developed across R_{47} is coupled through C_{20} to a single pole double throw selector switch, where it may be selected to control pulse generation channels (D) through (H).

Channels (D) through (H). CATHODE FOLLOWER, DELAY MULTIVIBRATOR, SLAVE
BLOCKING OSCILLATOR, CATHODE FOLLOWER

Channels (D), (E), (F), (G), and (H) are identical in circuitry and function. In describing the actions of these channels reference will be made only to drawing EA6, Channel (D) of Modulator. For building and identifying components in the other pulse generation channels a cross-reference table is included, see pages 46 and 47.

Action in pulse generation channel (D) is inaugurated by a fixed positive pulse selected from channel (B) by switch S_3 , or by a positive pulse wobbled timewise at an audio frequency selected from Channel (C) by the same switch, S_3 . This positive pulse, fixed or wobbled, is coupled through isolation cathode follower V_{43} to the grid of V_{14} , the normally OFF half of the variable delay multivibrator V_{14} - V_{15} . The grid of V_{14} is maintained below cutoff potential by a fixed d-c bias of -27 volts.

The output of this multivibrator is a positive square pulse appearing at the plate of V_{15} . The width of this pulse, i.e. the after edge, is variable using potentiometer R_7 on the front panel. This square wave is differentiated in the circuit of C_{48} and the plate coil of T_4 . The negative pulse, resulting from differentiating the after edge causes the slave blocking oscillator to cycle. A positive pulse, .2 microsecond wide, is developed across the 100 ohm cathode resistor, R_{84} . This signal is coupled through a cathode follower, V_{17} for purposes of isolation, and thence to crystal diode Y_{12} .

Consider the function $f(x)$ defined on the interval $[0, 1]$ by

$f(x) = \begin{cases} x^2 & \text{if } 0 \leq x \leq 1/2 \\ 2x - x^2 & \text{if } 1/2 < x \leq 1 \end{cases}$

and let $F(x)$ be the function defined on $[0, 1]$ by $F(x) = \int_0^x f(t) dt$. Show that $F(x)$ is a function which is continuous on $[0, 1]$ and that $F'(x) = f(x)$ for all x in $[0, 1]$.

Let $f(x)$ be a function defined on the interval $[a, b]$ and let $F(x)$ be the function defined on $[a, b]$ by $F(x) = \int_a^x f(t) dt$. Show that $F(x)$ is a function which is continuous on $[a, b]$ and that $F'(x) = f(x)$ for all x in $[a, b]$.

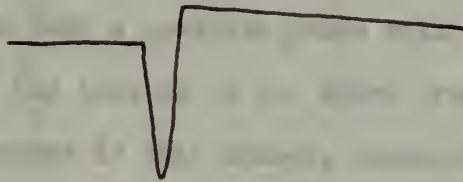
Let $f(x)$ be a function defined on the interval $[a, b]$ and let $F(x)$ be the function defined on $[a, b]$ by $F(x) = \int_a^x f(t) dt$. Show that $F(x)$ is a function which is continuous on $[a, b]$ and that $F'(x) = f(x)$ for all x in $[a, b]$.

Channel K. INVERTER AMPLIFIERS AND CATHODE FOLLOWERS

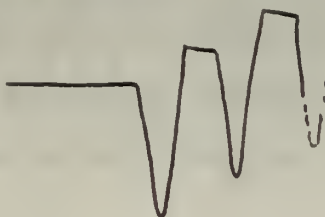
In this, the final channel, the five positive pulses generated in pulse generation channels (D) through (H) are combined, amplified and coupled to BNC output connectors through isolation stages.

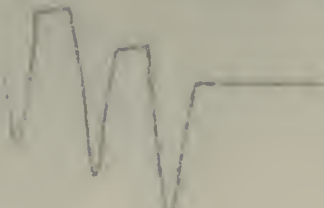
Referring now to figure EA7 and the waveforms for channel (K), a series of five pulses is coupled through C_{32} to the control grid of V_{41} , a fairly high g_m , high efficiency power pentode operated as a class A amplifier. This tube is of miniature construction and is characterized by low interelectrode capacitances and high perveance, so is well adapted to high frequency and wide band service. R_{58} and R_{59} form a voltage divider network which provides a fixed bias of -30 volts. By so operating the stage, (fixed bias) the effect of degeneration, present with grid leak or cathode bias, is avoided and greater gain is obtained.

Without some means of limiting, the waveforms at the plate of this stage are as shown below (considering a single pulse):

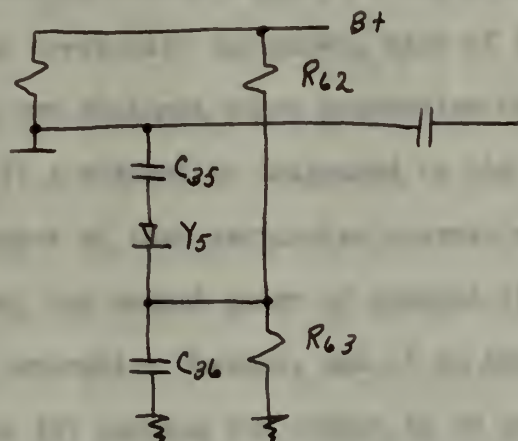


When several pulses, closely spaced are present, each pulse rides in the combined overshoots of those pulses preceding it and the effect indicated below results:



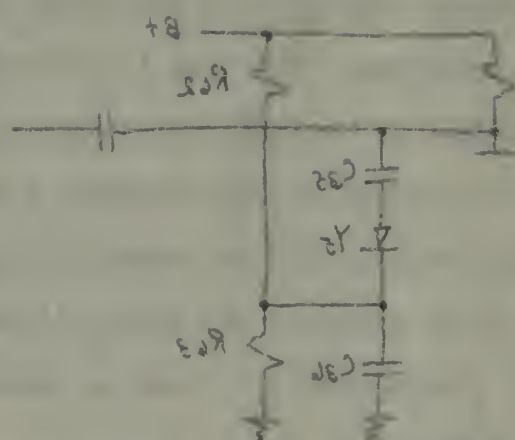


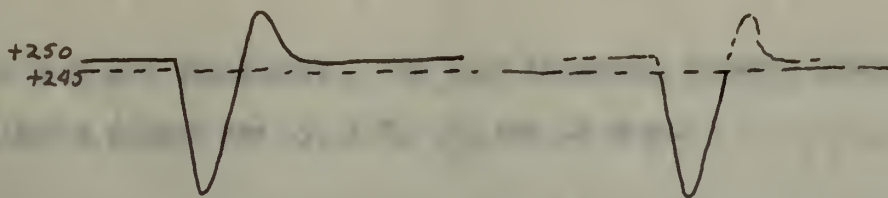
The grid pulses are clean, so the transient is the result of the discharge of stray capacitances in the plate circuit. By using the network below this objectionable effect is eliminated:



The plate of the tube is normally at about 250 volts. Voltage divider network R62 and R63 maintains the lower end of the crystal, a CK708, at about 245 volts. The crystal, being a unidirectional device, is arranged so that a positive pulse will be passed from the upper to the lower end (as located in the above drawing). With the circuit elements connected in this manner, whenever the plate of V₄₁ is more positive than about 245 volts the crystal presents a low impedance of approximately 350 ohms, and so very effectively clips the overshoot. This is demonstrated in the sketch following:

The first section of the report is devoted to a description of the work done during the year. It is divided into three parts: a general description of the work, a description of the work done in the various departments, and a description of the work done in the various sections of the departments.



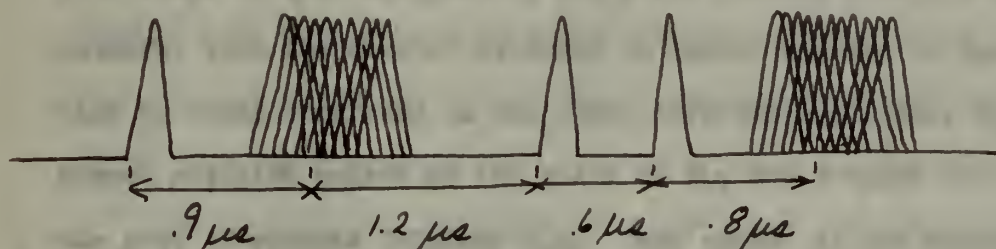


Before following the pulses on through the remainder of Channel (K), mention should be made of the flexibility of the pulse train.

As previously explained, each of these five pulses is generated in its own distinct pulse generation channel, channels (D) through (H). If a channel is triggered by the fixed pulse from channel (B), the output of that particular channel will be a fixed pulse. If, instead, the output pulse of channel (C) is used for triggering a pulse generation channel, and if an audio signal is being fed into channel (C) causing its output to be frequency modulated, then the output pulse of that pulse generation channel will also be frequency modulated (wobulated in time).

Depending on the position of switches SW_3 through SW_7 , the train of five pulses which is coupled to grid 1 of V_{11} may be constituted of any combination of fixed or wobulated pulses. The pulses may be positioned relative to each other by controls R_7 , R_9 , R_{10} , R_{11} , and R_{12} . Furthermore, all pulses in the train which are produced through action of the trigger pulse from channel (B) can be positioned simultaneously by control R_{30} . The same is true for pulses generated in channels triggered from channel (C), control in time here being effected by R_2 . As an example, in the accompanying figure a typical pulse train is drawn. The second and fifth pulses are shown being wobulated at an audio rate, say 1000 cy/sec. Pulses one, three,

and four are stationary. The time intervals between leading edges of adjacent pulses are .9, 1.2, .6, and .8 usec.

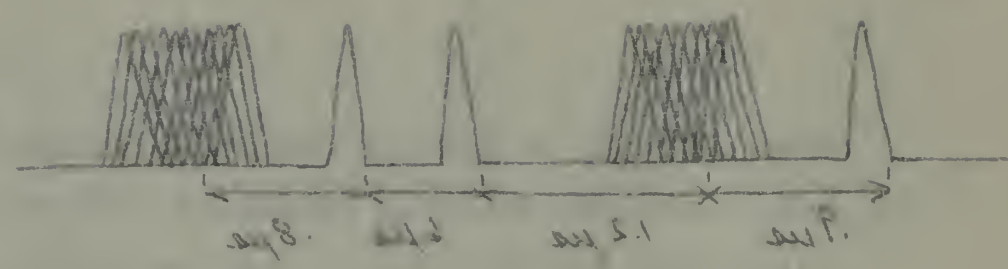


This pulse train is inverted and amplified by V_{41} , shaped by the crystal network and coupled into cathode follower V_{48} for isolation purposes. The pulses on the grid of the cathode follower are negative. If these waveforms are to appear on the cathode of this stage, the grid must be maintained at a positive potential of such magnitude that the tube is not cutoff by the negative input pulses, since this would result in unwanted clipping and distortion of the pulses.

A voltage divider composed of R_{64} and R_{65} furnishes a positive bias of 125 volts under dynamic conditions. This maintains the grid at a proper level to prevent grid clipping. Considerable grid current is drawn, of course, and this injects a grid leak bias into the circuit for consideration. The plus 125 volts desired, and obtained, is the result of fixed plus grid leak bias and, as noted above, is the condition prevailing when the equipment is in operation.

The negative pulse developed across R_{66} is coupled through C_{39} to the BNC fitting on the front panel labeled NEG. OUT. The capacitor C_{39} serves to prevent the tube from burning out in the event a d-c short to ground is placed across the output terminals.

and from the following: The first two curves are plotted on the same scale as the adjacent curves are 1/2, 1/2, 1/2, and 1/2.



This figure shows the results of the analysis of the signals received from the various stations. The signals are shown in the order of their frequency. The first signal is a series of sharp peaks, which is a result of the fact that the signal is a series of pulses. The second and third signals are single sharp peaks, which are a result of the fact that the signal is a single pulse. The fourth signal is a single sharp peak, which is a result of the fact that the signal is a single pulse. The labels below the axis indicate the frequency of each signal: 8 Hz, 1 Hz, 1.5 Hz, and 7 Hz.

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A small portion of the negative pulse appearing at the cathode of V_{48} is coupled to the grid of V_{47} , another 6AN5 inverter-amplifier. This stage is also equipped in the plate circuit with a pulse clipping network, with the crystal reversed to handle signals of opposite polarities to those occurring in the first inverter-amplifier, V_{41} . The shaped positive pulses at the plate of V_{47} are coupled through C_{41} to the grid of cathode follower V_{49} . They appear at the cathode of the same tube and are coupled through a d-c isolation capacitor, C_{40} , to the BNC fitting on the front panel labeled POS. OUT.

[illegible]

POWER SUPPLY

The power supply for the subject unit is included as an integral part of that unit. However, the chassis on which it is built can be disconnected from the main chassis merely by breaking the 14 wire connector plug between the two units and removing the fastener bolts holding the two chassis together.

The power supply furnishes plus 260 volts for plate supply and a -42 volt supply for biasing purposes. It also furnishes a filament supply of 6.3 volts, and, although not at present connected to the coupling plug, could furnish a 5 volt filament supply.

The high voltage transformer is a Stancor Universal Type, #P-6314. The plate or secondary furnishes 700 volts, center tapped, at 200 mils. Two filament winding supply 5 volts, center tapped, at 3 amps and 6.3 volts, center tapped, at 5.5 amps. The transformer weighs about 7.7 pounds and has a mounting area of 4.5" X 3.75".

The total filament current drain exceeds the 5.5 amp rating so a separate filament transformer is employed. This transformer is a Stancor Single Secondary Type, #P-6308. The secondary supplies 6.3 v, center tapped, at 10 amps which exceeds somewhat the total filament drain. This filament drain is about 9 amps. The transformer weighs about four pounds and requires a mounting area of 2.8" X 3.2".

Several other equivalent transformers are available commercially and may be substituted if those listed above are unavailable. The P-6314 may be replaced by a Chicago Cat. #PH-200, or U.T.C. Cat. #R-109, or a Thordarson Cat. #T-22R07. The P-6308 has an equivalent in a Chicago Cat. #F-610, a U.T.C. Cat. #CG-122 or an S-61, and a

1950-1951
The power supply for the motor is connected to an internal
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through a switch. The switch is connected to the power supply
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through a switch.

Thordarson Cat. #T-21F12.

For rectification, three 6X4 full wave rectifiers are connected in parallel. These miniature tubes have a max. dc output current handling capacity of 70 ma a piece or 210 ma for the parallel combination.

A pi type C-L-C smoothing filter is employed. The capacitors used are 40 microfarad, plug in type (using octal socket) electrolytics, rated at 450 working volts.

The single filter choke in the network is a Stancor Heavy Duty Type, #C-1721, 8.5 henries and rated at 200 ma. Its d-c resistance is 120 ohms, weight about 4 pounds and mounting dimensions 3.2" x 3.3". Other commercial equivalents are Chicago Cat. #RC-8200 and Thordaraon Cat. #T-20C55, 56.

A 6AS7G, low mu twin power triode is used as a current control tube. This glass octal tube is the only non-miniature employed in the entire unit. The current handling capacity is 125 ma per section. The bias control tube is a 6AK5 sharp cutoff pentode. An OA2 glow-discharge diode is used, for a 150 volt voltage regulator. A divider network, R₁₅ and R₈, provides bias control for the 6AK5. The positive and negative output voltages are taken off across R₁₈ and R₂₀ respectively, a bleeder network.

In detail the regulated power supply functions as follows:

The 115 volt ac input voltage is stepped up by T₉ to 700 volts. The secondary is center tapped so that 350 volts (rms) is applied across each section of the full wave rectifiers. The two halves of the rectifiers conduct alternately as each plate is made positive by the secondary of the transformer. The capacitors C₁ and C₂ charge

The first thing I noticed when I stepped out of the car was the smell of the sea. It was a fresh, salty smell that I had never before. I took a deep breath and felt a sense of peace. The sun was shining brightly, and the water was a beautiful blue. I walked along the beach, feeling the sand under my feet. The waves were crashing against the shore, and I could hear the seagulls in the distance. It was a perfect day, and I was finally alone.

The beach was empty, and I was the only person there. I walked along the shore, looking at the waves. They were so beautiful, and I had never seen them before. The sun was shining brightly, and the water was a beautiful blue. I took a deep breath and felt a sense of peace. The sand was soft and warm, and I could feel it under my feet. The waves were crashing against the shore, and I could hear the seagulls in the distance. It was a perfect day, and I was finally alone.

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when the rectifiers conduct and discharge through the bleeder network when the tube is not conducting. The choke tends to keep a constant current flowing in the same direction through the load, due to the build-up and collapse of its magnetic field when the current increases and decreases.

The voltage (d-c) at the positive end of C_1 is 400 volts when the equipment is in full operation. The potential across C_2 is 375 volts. This means a drop of 25 volts occurring across the choke, L_1 .

The current being drawn is then

$$25v/120 \text{ ohms} = 208 \text{ ma.}$$

This current is divided three ways between the 6X4's, i.e. 69 ma per tube. The drop across the rectifiers is

$$69 \text{ ma} \times 150 \text{ ohms} = 10.4 \text{ volts.}$$

The 150 ohms is the approximate total effective plate supply impedance per plate for the rectifiers.

The capacitor input to the filter is used to obtain a somewhat higher output voltage. The output voltages of the regulator are developed across the bleeder network R_{18} and R_{20} in parallel with the R_{15} - R_8 . R_{18} is also paralleled by the resistance of the load. All the load current must also flow through the plate to cathode resistance of V_{38} , the current control tube. All the other elements in the regulator circuit function to control this resistance of V_{38} and thereby maintain a constant load voltage.

The plate supply voltage of V_{39} is the regulated output, i.e. about 260 volts with respect to ground (or 302 volts with respect to the center tap of the secondary).

[illegible]

The bias on V_{39} is set by R_8 and so controls the current flow through the 6AK5. This current flows through R_{13} , an 82K plate resistor, causing a drop across it. This drop is the bias on V_{38} . Hence, the adjustment of R_8 establishes the normal plate resistance of V_1 . This adjustment is used to set the desired value of load voltage which the regulator is to maintain, in this case plus 260 volts.

Any tendency for the load or output voltage to drop tends to increase the bias on V_{39} . This results directly in a lower bias for V_{38} , which in turn means a lowering of the plate resistance of this tube. A smaller portion of the available voltage then appears across the tube and so the output load voltage remains practically constant.

The pentode is used for V_{39} because small variations in the load voltage are amplified sufficiently to insure proper operation of the regulator circuit.

To insure that the glow tube V_{34} will ionize when the power supply is first turned on its anode is connected through R_{14} to the plate of V_{39} .

The bleeder network in this regulator actually serves two purposes. It acts as a discharge path for the capacitors when power is removed, and it acts as a stabilizer to protect the voltage regulator at no load.

The bleeder current is

$$\frac{260v}{11.2K} = 23.2 \text{ ma}$$

which is about 11% of the total current.

Dissipation in R_{18} is

$$(.0232^2) (11200) = 6.3 \text{ watts}$$

The first part of the paper is devoted to the study of the
 properties of the function $f(x)$ defined by the series

$$f(x) = \sum_{n=0}^{\infty} a_n x^n$$
 where a_n are the coefficients of the series. It is shown that
 the function $f(x)$ is analytic in the region $|x| < 1$ and
 that it satisfies the functional equation

$$f(x) = 1 + x f(x^2)$$
 which is satisfied by the function $f(x) = \frac{1}{1-x}$. It is also shown
 that the function $f(x)$ is the unique solution of the functional
 equation $f(x) = 1 + x f(x^2)$ which is analytic in the region
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 that the function $f(x)$ is the unique solution of the functional
 equation $f(x) = 1 + x f(x^2)$ which is analytic in the region
 $|x| < 1$.

The total current flows through R_{20} . Across the resistance, 42 volts is developed, therefore its value is

$$\frac{42\text{v}}{208\text{ ma}} = 202\text{ ohms}$$

A twenty-watt, 500 ohm, wirewound resistor with a variable tap is used here and adjusted to the proper value of 202 ohms.

Plate dissipation in V_{38} is

$$(375 - (260 \text{ plus } 42)) \times .208 = 15.1 \text{ watts}$$

which is slightly above the rated max.

The cutoff or series resonant frequency for one LC section of the filter is

$$f_c = \frac{1}{2\pi\sqrt{LC}} = 8.62 \text{ cy/sec.}$$

The ripple voltage is $E_c \approx f_c^2 / f_o^2$

where $f_o = 120 \text{ cy/sec}$ for a full wave

rectifier. This gives a ripple voltage of $\left[\frac{8.62}{120}\right]^2 = 5.16 \times 10^{-3}$ or the ripple voltage is .516% of the input voltage.

The first step is to find the derivative of the function.

Let $f(x) = x^2 + 3x - 5$. Then the derivative is $f'(x) = 2x + 3$.

$$f'(x) = 2x + 3$$

A second step is to find the critical points of the function.

Set the derivative equal to zero and solve for x .

$$2x + 3 = 0$$

$$2x = -3$$

$$x = -\frac{3}{2}$$

The next step is to find the value of the function at the critical point.

$$f\left(-\frac{3}{2}\right)$$

$$f\left(-\frac{3}{2}\right) = \left(-\frac{3}{2}\right)^2 + 3\left(-\frac{3}{2}\right) - 5$$

$$= \frac{9}{4} - \frac{9}{2} - 5$$

$$= \frac{9}{4} - \frac{18}{4} - \frac{20}{4}$$

$$= \frac{9 - 18 - 20}{4}$$

$$= \frac{-29}{4}$$

COMMENTS AND OBSERVATIONS

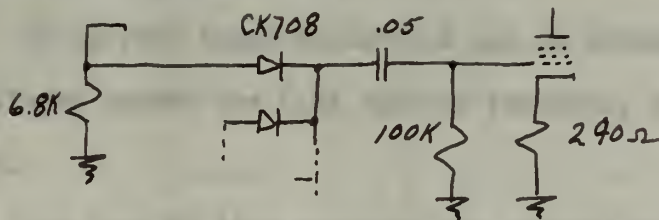
One of the most interesting and more difficult problems encountered in the design of this modulator unit occurred during work on the mixer section, Channel (K).

Clean positive pulses with no visible transients were obtained at the cathodes of V₁₇, V₂₁, V₂₅, V₂₉, and V₃₃ the output cathode follower stages of channels (D), (E), (F), (G), and (H) respectively. These positive going signals were transmitted through the unidirectional crystals Y₁₂ through Y₁₆ (one per channel) and, depending upon the settings of the delay controls in the delay multivibrator in each channel, a coded pulse train was obtained such as that in the accompanying figure,



when observed at the forward end junction of the five CK708 crystals.

The circuit involved was as follows:



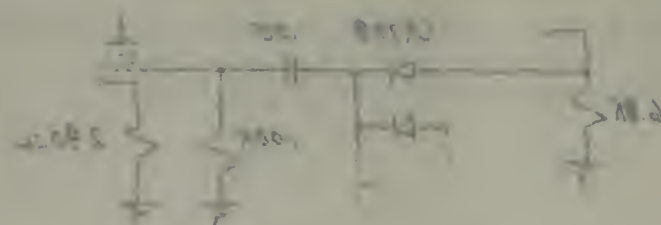
The wave shape could be broken down into, say, a stretched pulse with a long decay time plus a transient superimposed on the decaying trailing edge, i.e.

The first part of the experiment was to determine the effect of the frequency of the input signal on the output signal. The input signal was a sine wave with a frequency of 1 kHz. The output signal was measured at the output of the circuit. The results showed that the output signal was a sine wave with a frequency of 1 kHz. The amplitude of the output signal was approximately 1 V. The phase shift between the input and output signals was approximately 90 degrees. The second part of the experiment was to determine the effect of the input signal amplitude on the output signal. The input signal was a sine wave with a frequency of 1 kHz. The amplitude of the input signal was varied from 0.1 V to 1 V. The output signal was measured at the output of the circuit. The results showed that the output signal was a sine wave with a frequency of 1 kHz. The amplitude of the output signal was approximately 1 V. The phase shift between the input and output signals was approximately 90 degrees.

Figure 1

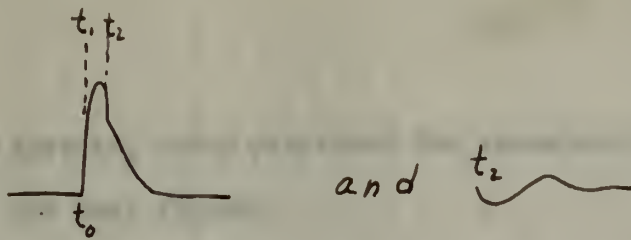


The circuit diagram is shown in Figure 2. The circuit consists of a 100 ohm resistor, a 100 ohm resistor, a 100 ohm resistor, and a 100 ohm resistor. The input signal is applied to the first resistor. The output signal is measured across the last resistor.

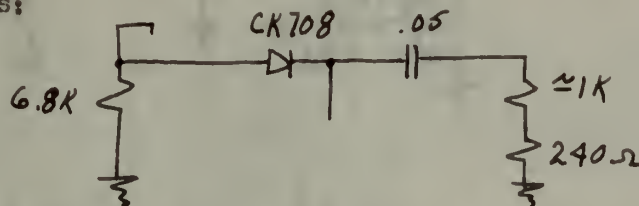


The results of the experiment are shown in Figure 3. The graph shows the output signal as a function of the input signal amplitude. The output signal is a sine wave with a frequency of 1 kHz. The amplitude of the output signal is approximately 1 V. The phase shift between the input and output signals is approximately 90 degrees.

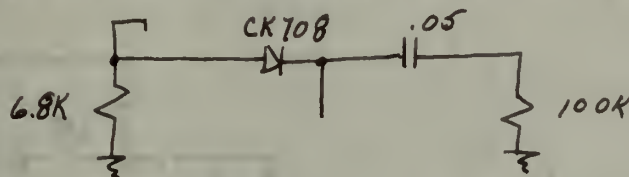
Figure 3



In the period from t_0 to t_2 the pulse shape was preserved. During the period t_1 to t_2 grid conduction occurred and the equivalent circuit was as follows:



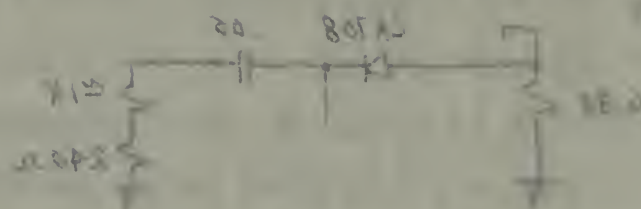
which gave a fairly small RC decay time. However, as soon as the signal fell to where grid conduction ceased, the equivalent circuit became



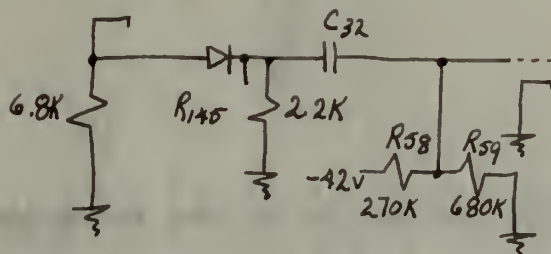
and the RC was increased over ten fold. The transient which occurred when the abrupt switch from grid conduction to non-conduction took place appeared as a natural result of the lead inductance in series with the coupling capacitance which form a series LC circuit. The high 100K damping resistance in the network prevented it from reaching any sizeable proportions.

To correct these conditions and so preserve the waveform as developed across the 6.8K cathode resistor, several changes were made.

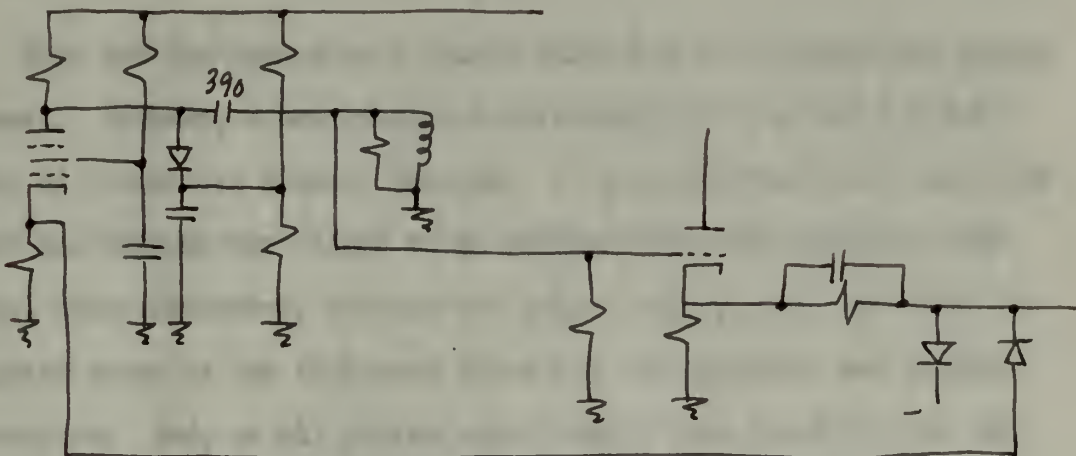
The long RC time constant was reduced by replacing the .05 capacitor with a .001 and a direct d-c discharge patch (2.2K to ground) included. Fixed bias replaced grid lead bias on the pentode amplifier and all leads were shortened as much as possible.



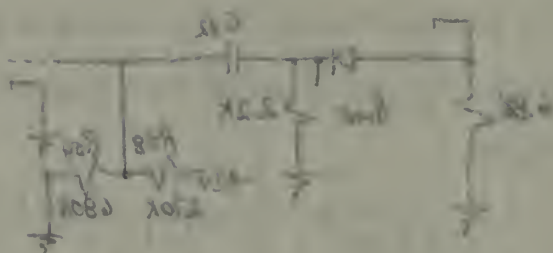
The new circuit, which preserved the waveshape very closely was as indicated in the next figure:

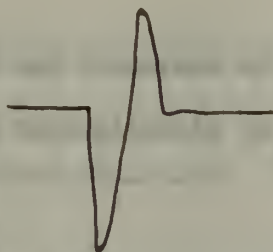


The first plate circuit for V_{41} built up on a breadboard was the following one:



The 390 micromicrofarad coupling capacitor was selected to series resonate with the peaking coil. The damping resistance across this coil was adjusted so that a waveform such as

[illegible]



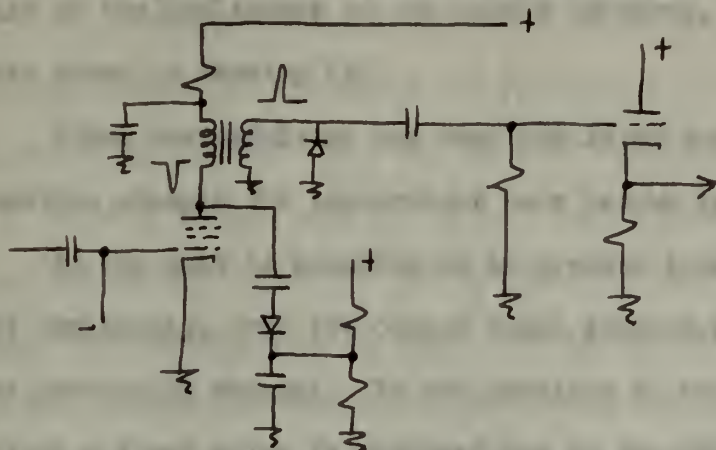
was obtained at the grid of the cathode follower. With the double limiting network in the output circuit of this cathode follower, a satisfactory positive pulse was obtained.



This was the case when a single pulse was put through the mixing channel. However, a new situation developed when the whole coded train of pulses was coupled through. It was now found that, when one pulse was brought very close to an adjacent one, the positive overshoot, which ultimately becomes the output pulse, rode down into the negative swing of the following pulse and its amplitude was greatly attenuated. And, as all pulses were brought into proximity and the negative swings were compounded, the output pulse train from the cathode follower took on this appearance:

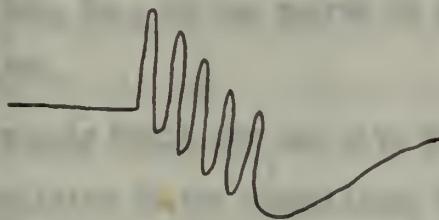


This arrangement was discarded as obviously unsatisfactory and a new circuit, as shown schematically in the next figure, was built:



In this circuit a step-up was obtained in the pulse transformer in the pentode plate circuit. The crystal diode in the secondary clipped any negative overshoot and the crystal network in the primary kept transients from appearing on the pulse developed at the plate of the pentode.

The output pulse train coupled to the cathode follower had the following appearance.



By varying the turns ratio of the pulse transformer, for details of which see drawing EA3, it was found that the remanance of the Ferroxcube core was sufficient, when a step up of 2:1 or greater was employed, that a "following" pulse occurred before the recovery time (of the core) was reached for a "preceding" pulse. Consequently, again there was the problem of one pulse introducing cross-talk upon another. A great many

This arrangement was designed as a means of measuring the
 the amount of light which is reflected from the surface of the



In this circuit, a variable capacitor is used to vary the
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By varying the amount of light which is reflected from the
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turns ratios, wire sizes, core sizes, etc. were tried before it was found more satisfactory to get away from the cores entirely, due to the size of the amplitudes of the pulses involved. The ultimate circuit is that shown in drawing EA7.

Since the modulator has been completed and has been used, several possible changes for improvement have become apparent.

As the unit is constructed at present there is no means for cutting out completely, from the output coded pulse train, the pulse from any one particular channel. In one position of the single pole double throw switch a fixed pulse is produced and in the other position a wobulating pulse is obtained. By replacing these two position toggles with types incorporating an OFF position, this undesirable condition can be rectified. Due to the circuit location of these switches no snuffer type contact mechanism, for eliminating pitting caused by arcing, is needed. A slow make, slow break type switch will allow decided economies over those switches designed for universal or d-c applications. The General Cement Mfg. Co., is one source of supply for this neutral center switch; Item #1308.

The power supply built for use with this unit utilizes a type 6AS7G as a current regulator in the stabilizing circuit. This is a rather large and unwieldy tube in a unit in which all other tubes are of miniature construction. This 6AS7G envelope protrudes even beyond the transformers and chokes used in the power supply. A new tube very recently brought out by the RCA Victor Division of the Radio Corporation of America is the type 6080. The 6080 is a low-mu, high perveance, twin power triode designed primarily for use as a regulator tube in

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stabilized d-c power supply units. It is similar to the 6AS7-G in characteristics, but is smaller in size and features conservative ratings.

In d-c amplifier applications, maximum ratings for each unit include a plate voltage of 250 volts, plate current of 125 ma and a plate dissipation of 13 watts. These ratings are identical with those for the 6AS7G.

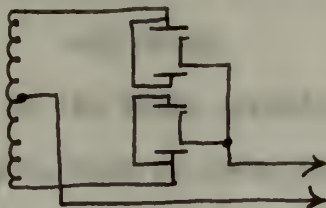
Another feature which might be changed, and so improve the unit, is the replacement of all 6J6 twin triodes by 5670's. This would reduce the types of tubes employed by one. The two types are similar except that the 6J6 employs a common cathode whereas each section of the 5670 has a separate cathode pin making this tube somewhat more versatile than the 6J6. This change would necessitate some readjustment of component values in the multivibrator circuits where the 6J6 is most frequently utilized.

Along this same line of thought it is noted that the tube V_6 uses $\frac{1}{2}$ 6J6 and the other half of this envelope is unused. Also V_{13} utilizes half of envelope X_{12} while the other half is idle. This offers an opportunity for reducing the tube complement by one.

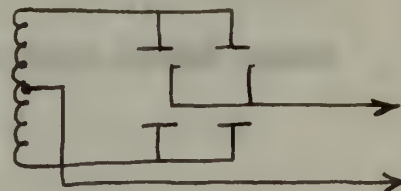
In the power supply the degree of regulation was sufficient to meet requirements of the unit. However, the margin was not great. In order to increase the sensitivity of the regulator to load changes, it may be desirable that a bias control tube, V_{39} , with a greater amplification than that afforded by the 6AK5 should be employed.

One final note about the power supply: It is generally regarded as more satisfactory to use both halves of a rectifier for the same phase and connect them thus,

The first thing I noticed when I stepped out of the car was the heat. It was a sticky, oppressive heat that seemed to wrap around me like a heavy blanket. I had heard that the weather in the South was terrible, but I didn't realize it would be this bad. The sun was beating down on me, and I could feel my skin starting to burn. I looked up at the sky, which was a brilliant, featureless blue. There were no clouds, no birds, nothing to break the monotony of the color. I took a deep breath, trying to get used to the air. It smelled different from the air I was used to in the North. It was thicker, more humid. I could feel it filling my lungs, making it harder to breathe. I walked a few steps, trying to get my bearings. The ground was hot underfoot, and I could hear the sound of my shoes crunching on the pavement. In the distance, I could see the outlines of buildings, but they were too far away to make out any details. I felt a little disoriented, like I was in a dream. I tried to remember where I was, but my mind was blank. I just knew that I was in a new place, a place that was very different from the one I had left behind. I took another deep breath, trying to steady myself. The heat was still there, but I was starting to get used to it. I was starting to feel like I belonged here.



rather than



However, this requires an even number of rectifier tubes and would involve increasing the tube complement by one.

The CK708 germanium crystal diodes used in numerous circuits throughout the design are a Raytheon product. Their important characteristics are as follows:

Max. d-c inverse voltage	100 v
Peak anode current	100 ma
Max. ave. d-c anode current	35 ma
Min. fwd. current at +1 volt	3 ma
Max. inverse current at -100 volts	.625 ma
Shunt capacitance	1 mmf

There are a number of other germanium diodes available with about the same characteristics. Among these are:

1N38	Sylvania
1N38	Kempton
1N52	General Electric

Germanium when compared with other semi-conductors used in point contact type diodes possesses the following advantages:

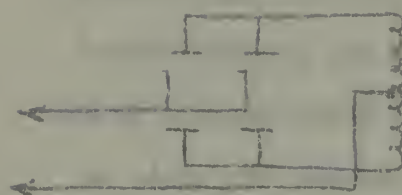


Figure 1



Figure 1 shows the circuit diagram of the system. The circuit consists of two parallel branches connected to a voltage source. The top branch contains a resistor and a capacitor in series, and the bottom branch contains a resistor and an inductor in series. The voltage source is represented by two horizontal arrows pointing to the left.

The circuit diagram is shown in Figure 1. The circuit consists of two parallel branches connected to a voltage source. The top branch contains a resistor and a capacitor in series, and the bottom branch contains a resistor and an inductor in series. The voltage source is represented by two horizontal arrows pointing to the left.

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1. The ability to withstand a much higher inverse voltage.
2. The ability to self-heal in cases where electrical breakdown may occur.

In the pulse transformer applications to which these crystal diodes are put, both of these advantages are an asset.

Summary of Front Panel Controls

Type Control	Labeled	Item No.	Function
Pot.	Reg	R ₈	Set regulated voltage
Pot.	Fixed (B)	R ₃₀	Delay Fixed Pulses
Pot.	Wob (C)	R ₂	Delay Wob. Pulses
Pot.	Coarse	R ₃	Adjust bias
Pot.	Fine	R ₄	Adjust bias
Pot.	Rep (A)	R ₅	Control rep. rate
BNC	Sync Out		
Toggle	Fix-Wob	SW ₃	Select Type Pulse
Toggle	Fix-Wob	SW ₄	Select Type Pulse
Toggle	Fix-Wob	SW ₅	Select Type Pulse
Toggle	Fix-Wob	SW ₆	Select Type Pulse
Toggle	Fix-Wob	SW ₇	Select Type Pulse
BNC	Audio-In		
Pot.	Chan. D	R ₇	Delay Pulse
Pot.	Chan. E	R ₉	Delay Pulse
Pot.	Chan. F	R ₁₀	Delay Pulse
Pot.	Chan. G	R ₁₁	Delay Pulse
Pot.	Chan. H	R ₁₂	Delay Pulse
Receptacle	115 v a-c		
Toggle	Fil.	SW ₁	Operate Fil. Xfmr
Toggle	H.V.	SW ₂	Operate H.V. Xfmr
BNC	Neg. Out		
BNC	Pos. Out		

Item No.	Quantity	Description	Unit	Price	Total
1	100	100	100	100	100
2	100	100	100	100	100
3	100	100	100	100	100
4	100	100	100	100	100
5	100	100	100	100	100
6	100	100	100	100	100
7	100	100	100	100	100
8	100	100	100	100	100
9	100	100	100	100	100
10	100	100	100	100	100
11	100	100	100	100	100
12	100	100	100	100	100
13	100	100	100	100	100
14	100	100	100	100	100
15	100	100	100	100	100
16	100	100	100	100	100
17	100	100	100	100	100
18	100	100	100	100	100
19	100	100	100	100	100
20	100	100	100	100	100
21	100	100	100	100	100
22	100	100	100	100	100
23	100	100	100	100	100
24	100	100	100	100	100
25	100	100	100	100	100
26	100	100	100	100	100
27	100	100	100	100	100
28	100	100	100	100	100
29	100	100	100	100	100
30	100	100	100	100	100
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57	100	100	100	100	100
58	100	100	100	100	100
59	100	100	100	100	100
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61	100	100	100	100	100
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87	100	100	100	100	100
88	100	100	100	100	100
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90	100	100	100	100	100
91	100	100	100	100	100
92	100	100	100	100	100
93	100	100	100	100	100
94	100	100	100	100	100
95	100	100	100	100	100
96	100	100	100	100	100
97	100	100	100	100	100
98	100	100	100	100	100
99	100	100	100	100	100
100	100	100	100	100	100

Vacuum Tube Summary

<u>Tube</u>	<u>Type</u>	<u>Channel</u>	<u>Function</u>
V ₁	1/2 6J6	C	Delay Multivibrator
V ₂ (X ₁)	1/2 6J6	C	Delay Multivibrator
V ₃	1/2 5670	C	Diode Clipper
V ₄ (X ₃)	1/2 5670	C	Inverter-Amplifier
V ₅	1/2 5670	C	Cathode Follower
V ₆	1/2 6J6	C	Audio Amplifier
V ₇	6C4	C	Slave Blocking Oscillator
V ₉	1/2 6J6	B	Delay Multivibrator
V ₁₀ (X ₉)	1/2 6J6	B	Delay Multivibrator
V ₁₁	6C4	B	Slave Blocking Oscillator
V ₁₃ (X ₁₂)	1/2 5670	A	Free Running Blocking Oscillator
V ₁₄	1/2 6J6	D	Delay Multivibrator
V ₁₅ (X ₁₄)	1/2 6J6	D	Delay Multivibrator
V ₁₆	6C4	D	Slave Blocking Oscillator
V ₁₇	1/2 5670	D	Cathode Follower
V ₁₈	1/2 6J6	E	Delay Multivibrator
V ₁₉ (X ₁₈)	1/2 6J6	E	Delay Multivibrator
V ₂₀	6C4	E	Slave Blocking Oscillator
V ₂₁ (X ₁₇)	1/2 5670	E	Cathode Follower
V ₂₂	1/2 6J6	F	Delay Multivibrator
V ₂₃ (X ₂₂)	1/2 6J6	F	Delay Multivibrator
V ₂₄	6C4	F	Slave Blocking Oscillator
V ₂₅	1/2 5670	F	Cathode Follower

TABLE 1

Location	Season	Year	Value
Upper Meridional	1	1950	1.2
Upper Meridional	2	1951	1.4 (2)
Upper Meridional	3	1952	1.5
Upper Meridional	4	1953	1.6 (2)
Upper Meridional	5	1954	1.7
Upper Meridional	6	1955	1.8
Upper Meridional	7	1956	1.9
Upper Meridional	8	1957	2.0
Upper Meridional	9	1958	2.1 (2)
Upper Meridional	10	1959	2.2
Upper Meridional	11	1960	2.3 (2)
Upper Meridional	12	1961	2.4
Upper Meridional	13	1962	2.5 (2)
Upper Meridional	14	1963	2.6
Upper Meridional	15	1964	2.7
Upper Meridional	16	1965	2.8 (2)
Upper Meridional	17	1966	2.9
Upper Meridional	18	1967	3.0 (2)
Upper Meridional	19	1968	3.1
Upper Meridional	20	1969	3.2 (2)
Upper Meridional	21	1970	3.3
Upper Meridional	22	1971	3.4 (2)
Upper Meridional	23	1972	3.5
Upper Meridional	24	1973	3.6 (2)
Upper Meridional	25	1974	3.7
Upper Meridional	26	1975	3.8 (2)
Upper Meridional	27	1976	3.9
Upper Meridional	28	1977	4.0 (2)
Upper Meridional	29	1978	4.1
Upper Meridional	30	1979	4.2 (2)
Upper Meridional	31	1980	4.3
Upper Meridional	32	1981	4.4 (2)
Upper Meridional	33	1982	4.5
Upper Meridional	34	1983	4.6 (2)
Upper Meridional	35	1984	4.7
Upper Meridional	36	1985	4.8 (2)
Upper Meridional	37	1986	4.9
Upper Meridional	38	1987	5.0 (2)
Upper Meridional	39	1988	5.1
Upper Meridional	40	1989	5.2 (2)
Upper Meridional	41	1990	5.3
Upper Meridional	42	1991	5.4 (2)
Upper Meridional	43	1992	5.5
Upper Meridional	44	1993	5.6 (2)
Upper Meridional	45	1994	5.7
Upper Meridional	46	1995	5.8 (2)
Upper Meridional	47	1996	5.9
Upper Meridional	48	1997	6.0 (2)
Upper Meridional	49	1998	6.1
Upper Meridional	50	1999	6.2 (2)
Upper Meridional	51	2000	6.3
Upper Meridional	52	2001	6.4 (2)
Upper Meridional	53	2002	6.5
Upper Meridional	54	2003	6.6 (2)
Upper Meridional	55	2004	6.7
Upper Meridional	56	2005	6.8 (2)
Upper Meridional	57	2006	6.9
Upper Meridional	58	2007	7.0 (2)
Upper Meridional	59	2008	7.1
Upper Meridional	60	2009	7.2 (2)
Upper Meridional	61	2010	7.3
Upper Meridional	62	2011	7.4 (2)
Upper Meridional	63	2012	7.5
Upper Meridional	64	2013	7.6 (2)
Upper Meridional	65	2014	7.7
Upper Meridional	66	2015	7.8 (2)
Upper Meridional	67	2016	7.9
Upper Meridional	68	2017	8.0 (2)
Upper Meridional	69	2018	8.1
Upper Meridional	70	2019	8.2 (2)
Upper Meridional	71	2020	8.3
Upper Meridional	72	2021	8.4 (2)
Upper Meridional	73	2022	8.5
Upper Meridional	74	2023	8.6 (2)
Upper Meridional	75	2024	8.7
Upper Meridional	76	2025	8.8 (2)
Upper Meridional	77	2026	8.9
Upper Meridional	78	2027	9.0 (2)
Upper Meridional	79	2028	9.1
Upper Meridional	80	2029	9.2 (2)
Upper Meridional	81	2030	9.3
Upper Meridional	82	2031	9.4 (2)
Upper Meridional	83	2032	9.5
Upper Meridional	84	2033	9.6 (2)
Upper Meridional	85	2034	9.7
Upper Meridional	86	2035	9.8 (2)
Upper Meridional	87	2036	9.9
Upper Meridional	88	2037	10.0 (2)
Upper Meridional	89	2038	10.1
Upper Meridional	90	2039	10.2 (2)
Upper Meridional	91	2040	10.3
Upper Meridional	92	2041	10.4 (2)
Upper Meridional	93	2042	10.5
Upper Meridional	94	2043	10.6 (2)
Upper Meridional	95	2044	10.7
Upper Meridional	96	2045	10.8 (2)
Upper Meridional	97	2046	10.9
Upper Meridional	98	2047	11.0 (2)
Upper Meridional	99	2048	11.1
Upper Meridional	100	2049	11.2 (2)
Upper Meridional	101	2050	11.3
Upper Meridional	102	2051	11.4 (2)
Upper Meridional	103	2052	11.5
Upper Meridional	104	2053	11.6 (2)
Upper Meridional	105	2054	11.7
Upper Meridional	106	2055	11.8 (2)
Upper Meridional	107	2056	11.9
Upper Meridional	108	2057	12.0 (2)
Upper Meridional	109	2058	12.1
Upper Meridional	110	2059	12.2 (2)
Upper Meridional	111	2060	12.3
Upper Meridional	112	2061	12.4 (2)
Upper Meridional	113	2062	12.5
Upper Meridional	114	2063	12.6 (2)
Upper Meridional	115	2064	12.7
Upper Meridional	116	2065	12.8 (2)
Upper Meridional	117	2066	12.9
Upper Meridional	118	2067	13.0 (2)
Upper Meridional	119	2068	13.1
Upper Meridional	120	2069	13.2 (2)
Upper Meridional	121	2070	13.3
Upper Meridional	122	2071	13.4 (2)
Upper Meridional	123	2072	13.5
Upper Meridional	124	2073	13.6 (2)
Upper Meridional	125	2074	13.7
Upper Meridional	126	2075	13.8 (2)
Upper Meridional	127	2076	13.9
Upper Meridional	128	2077	14.0 (2)
Upper Meridional	129	2078	14.1
Upper Meridional	130	2079	14.2 (2)
Upper Meridional	131	2080	14.3
Upper Meridional	132	2081	14.4 (2)
Upper Meridional	133	2082	14.5
Upper Meridional	134	2083	14.6 (2)
Upper Meridional	135	2084	14.7
Upper Meridional	136	2085	14.8 (2)
Upper Meridional	137	2086	14.9
Upper Meridional	138	2087	15.0 (2)
Upper Meridional	139	2088	15.1
Upper Meridional	140	2089	15.2 (2)
Upper Meridional	141	2090	15.3
Upper Meridional	142	2091	15.4 (2)
Upper Meridional	143	2092	15.5
Upper Meridional	144	2093	15.6 (2)
Upper Meridional	145	2094	15.7
Upper Meridional	146	2095	15.8 (2)
Upper Meridional	147	2096	15.9
Upper Meridional	148	2097	16.0 (2)
Upper Meridional	149	2098	16.1
Upper Meridional	150	2099	16.2 (2)
Upper Meridional	151	2100	16.3
Upper Meridional	152	2101	16.4 (2)
Upper Meridional	153	2102	16.5
Upper Meridional	154	2103	16.6 (2)
Upper Meridional	155	2104	16.7
Upper Meridional	156	2105	16.8 (2)
Upper Meridional	157	2106	16.9
Upper Meridional	158	2107	17.0 (2)
Upper Meridional	159	2108	17.1
Upper Meridional	160	2109	17.2 (2)
Upper Meridional	161	2110	17.3
Upper Meridional	162	2111	17.4 (2)
Upper Meridional	163	2112	17.5
Upper Meridional	164	2113	17.6 (2)
Upper Meridional	165	2114	17.7
Upper Meridional	166	2115	17.8 (2)
Upper Meridional	167	2116	17.9
Upper Meridional	168	2117	18.0 (2)
Upper Meridional	169	2118	18.1
Upper Meridional	170	2119	18.2 (2)
Upper Meridional	171	2120	18.3
Upper Meridional	172	2121	18.4 (2)
Upper Meridional	173	2122	18.5
Upper Meridional	174	2123	18.6 (2)
Upper Meridional	175	2124	18.7
Upper Meridional	176	2125	18.8 (2)
Upper Meridional	177	2126	18.9
Upper Meridional	178	2127	19.0 (2)
Upper Meridional	179	2128	19.1
Upper Meridional	180	2129	19.2 (2)
Upper Meridional	181	2130	19.3
Upper Meridional	182	2131	19.4 (2)
Upper Meridional	183	2132	19.5
Upper Meridional	184	2133	19.6 (2)
Upper Meridional	185	2134	19.7
Upper Meridional	186	2135	19.8 (2)
Upper Meridional	187	2136	19.9
Upper Meridional	188	2137	20.0 (2)
Upper Meridional	189	2138	20.1
Upper Meridional	190	2139	20.2 (2)
Upper Meridional	191	2140	20.3
Upper Meridional	192	2141	20.4 (2)
Upper Meridional	193	2142	20.5
Upper Meridional	194	2143	20.6 (2)
Upper Meridional	195	2144	20.7
Upper Meridional	196	2145	20.8 (2)
Upper Meridional	197	2146	20.9
Upper Meridional	198	2147	21.0 (2)
Upper Meridional	199	2148	21.1
Upper Meridional	200	2149	21.2 (2)
Upper Meridional	201	2150	21.3
Upper Meridional	202	2151	21.4 (2)
Upper Meridional	203	2152	21.5
Upper Meridional	204	2153	21.6 (2)
Upper Meridional	205	2154	21.7
Upper Meridional	206	2155	21.8 (2)
Upper Meridional	207	2156	21.9
Upper Meridional	208	2157	22.0 (2)
Upper Meridional	209	2158	22.1
Upper Meridional	210	2159	22.2 (2)
Upper Meridional	211	2160	22.3
Upper Meridional	212	2161	22.4 (2)
Upper Meridional	213	2162	22.5
Upper Meridional	214	2163	22.6 (2)
Upper Meridional	215	2164	22.7
Upper Meridional	216	2165	22.8 (2)
Upper Meridional	217	2166	22.9
Upper Meridional	218	2167	23.0 (2)
Upper Meridional	219	2168	23.1
Upper Meridional	220	2169	23.2 (2)
Upper Meridional	221	2170	23.3
Upper Meridional	222	2171	23.4 (2)
Upper Meridional	223	2172	23.5
Upper Meridional	224	2173	23.6 (2)
Upper Meridional	225	2174	23.7
Upper Meridional	226	2175	23.8 (2)
Upper Meridional	227	2176	23.9
Upper Meridional	228	2177	24.0 (2)
Upper Meridional	229	2178	24.1
Upper Meridional	230	2179	24.2 (2)
Upper Meridional	231	2180	24.3
Upper Meridional	232	2181	24.4 (2)
Upper Meridional	233	2182	24.5
Upper Meridional	234	2183	24.6 (2)
Upper Meridional	235	2184	24.7
Upper Meridional	236	2185	24.8 (2)
Upper Meridional	237	2186	24.9
Upper Meridional	238	2187	25.0 (2)
Upper Meridional	239	2188	25.1
Upper Meridional	240	2189	25.2 (2)
Upper Meridional	241	2190	25.3
Upper Meridional	242	2191	25.4 (2)
Upper Meridional	243	2192	25.5
Upper Meridional	244	2193	25.6 (2)
Upper Meridional	245	2194	25.7
Upper Meridional	246	2195	25.8 (2)
Upper Meridional	247	2196	25.9
Upper Meridional	248	2197	26.0 (2)
Upper Meridional	249	2198	26.1
Upper Meridional	250	2199	26.2 (2)
Upper Meridional	251	2200	26.3
Upper Meridional	252	2201	26.4 (2)
Upper Meridional	253	2202	26.5
Upper Meridional	254	2203	26.6 (2)
Upper Meridional	255	2204	26.7
Upper Meridional	256	2205	26.8 (2)
Upper Meridional	257	2206	26.9
Upper Meridional	258	2207	27.0 (2)
Upper Meridional	259	2208	27.1
Upper Meridional	260	2209	27.2 (2)
Upper Meridional	261	2210	27.3
Upper Meridional	262	2211	27.4 (2)
Upper Meridional	263	2212	27.5
Upper Meridional	264	2213	27.6 (2)
Upper Meridional	265	2214	27.7
Upper Meridional	266	2215	27.8 (2)
Upper Meridional	267	2216	27.9
Upper Meridional	268	2217	28.0 (2)
Upper Meridional	269	2218	28.1
Upper Meridional	270	2219	28.2 (2)
Upper Meridional	271	2220	28.3
Upper Meridional	272	2221	28.4 (2)
Upper Meridional	273	2222	28.5
Upper Meridional	274	2223	28.6 (2)
Upper Meridional	275	2224	28.7
Upper Meridional	276	2225	28.8 (2)
Upper Meridional	277	2226	28.9
Upper Meridional	278	2227	29.0 (2)
Upper Meridional	279	2228	29.1
Upper Meridional	280	2229	29.2 (2)
Upper Meridional	281	2230	29.3
Upper Meridional	282	2231	29.4 (2)
Upper Meridional	283	2232	29.5
Upper Meridional	284	2233	29.6 (2)
Upper Meridional	285	2234	29.7
Upper Meridional	286	2235	29.8 (2)
Upper Meridional	287	2236	29.9
Upper Meridional	288	2237	30.0 (2)
Upper Meridional	289	2238	30.1
Upper Meridional	290	2239	30.2 (2)
Upper Meridional	291	2240	30.3
Upper Meridional	292	2241	30.4 (2)
Upper Meridional	293	2242	30.5
Upper Meridional	294	2243	30.6 (2)
Upper Meridional	295	2244	30.7
Upper Meridional	296	2245	30.8 (2)
Upper Meridional	297	2246	30.9

<u>Tube</u>	<u>Type</u>	<u>Channel</u>	<u>Function</u>
V ₂₆	1/2 6J6	G	Delay Multivibrator
V ₂₇ (X ₂₆)	1/2 6J6	G	Delay Multivibrator
V ₂₈	6C4	G	Slave Blocking Oscillator
V ₂₉ (X ₂₅)	1/2 5670	G	Cathode Follower
V ₃₀	1/2 6J6	H	Delay Multivibrator
V ₃₁ (X ₃₀)	1/2 6J6	H	Delay Multivibrator
V ₃₂	6C4	H	Slave Blocking Oscillator
V ₃₃	1/2 5670	H	Cathode Follower
V ₃₄	0A2	J	Voltage Regulator
V ₃₅	6X4	J	Full Wave Rectifier
V ₃₆	6X4	J	Full Wave Rectifier
V ₃₇	6X4	J	Full Wave Rectifier
V ₃₈	6AS7G	J	Current Control
V ₃₉	6AK5	J	Bias Control
V ₄₀	1/2 5670	G	Cathode Follower
V ₄₁	6AN5	K	Inverter-Amplifier
V ₄₃	1/2 5670	D	Cathode Follower
V ₄₄ (X ₅)	1/2 5670	E	Cathode Follower
V ₄₅ (X ₄₃)	1/2 5670	F	Cathode Follower
V ₄₆ (X ₄₀)	1/2 5670	H	Cathode Follower
V ₄₇	6AN5	K	Inverter-Amplifier
V ₄₈	1/2 5670	K	Cathode Follower
V ₄₉ (X ₄₈)	1/2 5670	K	Cathode Follower

Section	Number	Year	Price
Relief Administration	2	1911	1.00
Relief Administration	3	1912 (1st)	1.00
State Economic Council	4	1913	1.00
National Finance	5	1914 (2nd)	1.00
Relief Administration	6	1915	1.00
Relief Administration	7	1916 (1st)	1.00
State Economic Council	8	1917	1.00
National Finance	9	1918	1.00
Relief Administration	10	1919	1.00
Relief Administration	11	1920	1.00
Relief Administration	12	1921	1.00
Relief Administration	13	1922	1.00
Relief Administration	14	1923	1.00
Relief Administration	15	1924	1.00
Relief Administration	16	1925	1.00
Relief Administration	17	1926	1.00
Relief Administration	18	1927	1.00
Relief Administration	19	1928	1.00
Relief Administration	20	1929	1.00
Relief Administration	21	1930	1.00
Relief Administration	22	1931	1.00
Relief Administration	23	1932	1.00
Relief Administration	24	1933	1.00
Relief Administration	25	1934	1.00
Relief Administration	26	1935	1.00
Relief Administration	27	1936	1.00
Relief Administration	28	1937	1.00
Relief Administration	29	1938	1.00
Relief Administration	30	1939	1.00

All resistors $\frac{1}{2}$ watt unless otherwise noted.

<u>R</u>	<u>Channel</u>	<u>Size</u>	<u>R</u>	<u>Channel</u>	<u>Size</u>
2	C	500K 2W pot.	33	B	15K
3	C	100K 2W pot.	34	B	220 ohm
4	C	1K 2W pot.	35	B	10K 1W
5	A	5M 2W pot.	36	B	220K
7	D	500K 2W pot.	37	B	270K
8	J	100K 2W pot.	38	C	9.1K
9	E	500K 2W pot.	39	C	56K
10	F	500K 2W pot.	40	C	470K
11	G	500K 2W pot.	41	C	10K 1W
12	H	500K 2W pot.	42	C	560K
13	J	82K 1W	43	C	10K 1W
14	J	68K	44	C	47K
15	J	300K	45	C	6.8K
18	J	11.2K 5W	46	C	13.2K 1W
20	J	500 ohm 20W (tapped)	47	C	100 ohm
24	A	2.7K	48	C	5.1K
25	A	100 ohm	50	C	91 ohm
26	A	5.1K	51	C	13.8K 1W
27	B	10K 1W	52	C	100K
28	B	470K	53	C	6.8K
29	B	50K	54	C	100K
30	B	500K 2W pot.	55	C	910 ohm
31	B	560K	56	C	5.6K 1W
32	B	10K 1W	57	C	82K 1W

Table 1. Summary of data for the 1990-1991 season.

Year	Location	Altitude (m)	Area (ha)	Number of plots	Number of trees
1990	1000	1000	1000	1000	1000
1991	1000	1000	1000	1000	1000
1992	1000	1000	1000	1000	1000
1993	1000	1000	1000	1000	1000
1994	1000	1000	1000	1000	1000
1995	1000	1000	1000	1000	1000
1996	1000	1000	1000	1000	1000
1997	1000	1000	1000	1000	1000
1998	1000	1000	1000	1000	1000
1999	1000	1000	1000	1000	1000
2000	1000	1000	1000	1000	1000
2001	1000	1000	1000	1000	1000
2002	1000	1000	1000	1000	1000
2003	1000	1000	1000	1000	1000
2004	1000	1000	1000	1000	1000
2005	1000	1000	1000	1000	1000
2006	1000	1000	1000	1000	1000
2007	1000	1000	1000	1000	1000
2008	1000	1000	1000	1000	1000
2009	1000	1000	1000	1000	1000
2010	1000	1000	1000	1000	1000
2011	1000	1000	1000	1000	1000
2012	1000	1000	1000	1000	1000
2013	1000	1000	1000	1000	1000
2014	1000	1000	1000	1000	1000
2015	1000	1000	1000	1000	1000
2016	1000	1000	1000	1000	1000
2017	1000	1000	1000	1000	1000
2018	1000	1000	1000	1000	1000
2019	1000	1000	1000	1000	1000
2020	1000	1000	1000	1000	1000

<u>R</u>	<u>Channel</u>	<u>Size</u>	<u>R</u>	<u>Channel</u>	<u>Size</u>
58	K	270K	83	D	10K 1W
59	K	680K	84	D	100 ohm
60	K	1.5K 1W	85	D	220K
61	K	68K	86	D	270K
62	K	220K	87	D	820K
63	K	3.3M	88	D	6.8K
64	K	1M	89	E	820K
65	K	3.3M	90	E	6.8K
66	K	8.9K 2W	91	E	56K
67	K	41K	92	E	470K
68	K	4K	93	E	10K 1W
69	K	2.5K 1W	94	E	560K
70	K	68K	95	E	10K 1W
71	K	56K	96	E	15K
72	K	47K	97	E	10K 1W
73	K	3.3K	98	E	100 ohm
74	K	100K	99	E	220K
75	D	820K	100	E	270K
76	D	6.8K	101	E	820K
77	D	56K	102	E	6.8K
78	D	470K	103	F	820K
79	D	10K 1W	104	F	6.8K
80	D	560K	105	F	56K
81	D	10K 1W	106	F	470K
82	D	15K	107	F	10K 1W

Year	Count	Age	Year	Count	Age
1911	1	17	1912	2	18
1913	1	18	1914	1	19
1915	1	19	1916	1	20
1917	1	20	1918	1	21
1919	1	21	1920	1	22
1921	1	22	1922	1	23
1923	1	23	1924	1	24
1925	1	24	1926	1	25
1927	1	25	1928	1	26
1929	1	26	1930	1	27
1931	1	27	1932	1	28
1933	1	28	1934	1	29
1935	1	29	1936	1	30
1937	1	30	1938	1	31
1939	1	31	1940	1	32
1941	1	32	1942	1	33
1943	1	33	1944	1	34
1945	1	34	1946	1	35
1947	1	35	1948	1	36
1949	1	36	1950	1	37
1951	1	37	1952	1	38
1953	1	38	1954	1	39
1955	1	39	1956	1	40
1957	1	40	1958	1	41
1959	1	41	1960	1	42
1961	1	42	1962	1	43
1963	1	43	1964	1	44
1965	1	44	1966	1	45
1967	1	45	1968	1	46
1969	1	46	1970	1	47
1971	1	47	1972	1	48
1973	1	48	1974	1	49
1975	1	49	1976	1	50

<u>R</u>	<u>Channel</u>	<u>Size</u>
108	F	560K
109	F	10K 1W
110	F	15K
111	F	10K 1W
112	F	100 ohm
113	F	220K
114	F	270K
115	F	820K
116	F	6.8K
117	G	820K
118	G	6.8K
119	G	56K
120	G	470K
121	G	10K 1W
122	G	560K
123	G	10K 1W
124	G	15K
125	G	10K 1W
126	G	100 ohm
127	G	220K
128	G	270K
129	G	820K
130	G	6.8K
131	H	820K

<u>R</u>	<u>Channel</u>	<u>Size</u>
132	H	6.8K
133	H	56K
134	H	470K
135	H	10K 1W
136	H	560K
137	H	10K 1W
138	H	15K
139	H	10K 1W
140	H	100 ohm
141	H	220K
142	H	270K
143	H	820K
144	H	6.8K
145	H	2.2K
146	C	10K

Year	Amount	3	Year	Amount	3
1850	5	27	1860	5	28
1851	6	28	1861	6	29
1852	7	29	1862	7	30
1853	8	30	1863	8	31
1854	9	31	1864	9	32
1855	10	32	1865	10	33
1856	11	33	1866	11	34
1857	12	34	1867	12	35
1858	13	35	1868	13	36
1859	14	36	1869	14	37
1860	15	37	1870	15	38
1861	16	38	1871	16	39
1862	17	39	1872	17	40
1863	18	40	1873	18	41
1864	19	41	1874	19	42
1865	20	42	1875	20	43
1866	21	43	1876	21	44
1867	22	44	1877	22	45
1868	23	45	1878	23	46
1869	24	46	1879	24	47
1870	25	47	1880	25	48
1871	26	48	1881	26	49
1872	27	49	1882	27	50
1873	28	50	1883	28	51
1874	29	51	1884	29	52
1875	30	52	1885	30	53
1876	31	53	1886	31	54
1877	32	54	1887	32	55
1878	33	55	1888	33	56
1879	34	56	1889	34	57
1880	35	57	1890	35	58
1881	36	58	1891	36	59
1882	37	59	1892	37	60
1883	38	60	1893	38	61
1884	39	61	1894	39	62
1885	40	62	1895	40	63
1886	41	63	1896	41	64
1887	42	64	1897	42	65
1888	43	65	1898	43	66
1889	44	66	1899	44	67
1890	45	67	1900	45	68

All capacitors 200 WV unless otherwise noted.

<u>C</u>	<u>Channel</u>	<u>Size</u>	<u>C</u>	<u>Channel</u>	<u>Size</u>
1	J	40 mf 450 WV	27	C	.05
2	J	40 mf 450 WV	28	C	.05
5	A	100	29	C	400 300 WV
6	B	.05 300 WV	30	C	.25
7	B	100 300 WV	32	K	.001
8	B	100	33	K	.1 300 WV
9	B	32	34	K	.01 300 WV
10	B	62	35	K	.01
11	B	.002	36	K	.001 300 WV
12	B	.01 300 WV	37	K	.01 300 WV
13	B	.01	38	K	.01
14	B	.05	39	K	.01
15	C	100	40	K	400 300 WV
16	C	100 300 WV	41	K	.01 300 WV
17	C	5	42	K	.01
18	C	.002	43	K	.05
19	C	.1 300 WV	44	K	.01 300 WV
20	C	.01	45	D	100 300 WV
21	C	.005	46	D	100
22	C	100 300 WV	47	D	10 300 WV
23	C	200	48	D	62
24	C	.001 300 WV	49	D	.002
25	C	.068	50	D	.01 300 WV
26	C	.01	51	D	.01

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Q	Amount	Rate	Q	Amount	Rate
1	100	100	1	100	100
2	200	200	2	200	200
3	300	300	3	300	300
4	400	400	4	400	400
5	500	500	5	500	500
6	600	600	6	600	600
7	700	700	7	700	700
8	800	800	8	800	800
9	900	900	9	900	900
10	1000	1000	10	1000	1000
11	1100	1100	11	1100	1100
12	1200	1200	12	1200	1200
13	1300	1300	13	1300	1300
14	1400	1400	14	1400	1400
15	1500	1500	15	1500	1500
16	1600	1600	16	1600	1600
17	1700	1700	17	1700	1700
18	1800	1800	18	1800	1800
19	1900	1900	19	1900	1900
20	2000	2000	20	2000	2000
21	2100	2100	21	2100	2100
22	2200	2200	22	2200	2200
23	2300	2300	23	2300	2300
24	2400	2400	24	2400	2400
25	2500	2500	25	2500	2500
26	2600	2600	26	2600	2600
27	2700	2700	27	2700	2700
28	2800	2800	28	2800	2800
29	2900	2900	29	2900	2900
30	3000	3000	30	3000	3000
31	3100	3100	31	3100	3100
32	3200	3200	32	3200	3200
33	3300	3300	33	3300	3300
34	3400	3400	34	3400	3400
35	3500	3500	35	3500	3500
36	3600	3600	36	3600	3600
37	3700	3700	37	3700	3700
38	3800	3800	38	3800	3800
39	3900	3900	39	3900	3900
40	4000	4000	40	4000	4000
41	4100	4100	41	4100	4100
42	4200	4200	42	4200	4200
43	4300	4300	43	4300	4300
44	4400	4400	44	4400	4400
45	4500	4500	45	4500	4500
46	4600	4600	46	4600	4600
47	4700	4700	47	4700	4700
48	4800	4800	48	4800	4800
49	4900	4900	49	4900	4900
50	5000	5000	50	5000	5000

<u>C</u>	<u>Channel</u>	<u>Size</u>	<u>C</u>	<u>Channel</u>	<u>Size</u>
52	D	.05	76	G	.05
53	E	100 300 WV	77	H	100 300 WV
54	E	100	78	H	100
55	E	10 300 WV	79	H	10 300 WV
56	E	62	80	H	62
57	E	.002	81	H	.002
58	E	.01 300 WV	82	H	.01 300 WV
59	E	.01	83	H	.01
60	E	.05	84	H	.05
61	F	100 300 WV			
62	F	100			
63	F	10 300 WV			
64	F	62			
65	F	.002			
66	F	.01 300 WV			
67	F	.01			
68	F	.05			
69	G	100 300 WV			
70	G	100			
71	G	10 300 WV			
72	G	62			
73	G	.002			
74	G	.01 300 WV			
75	G	.01			

CROSS INDEX CHANNELS (D)-(H)

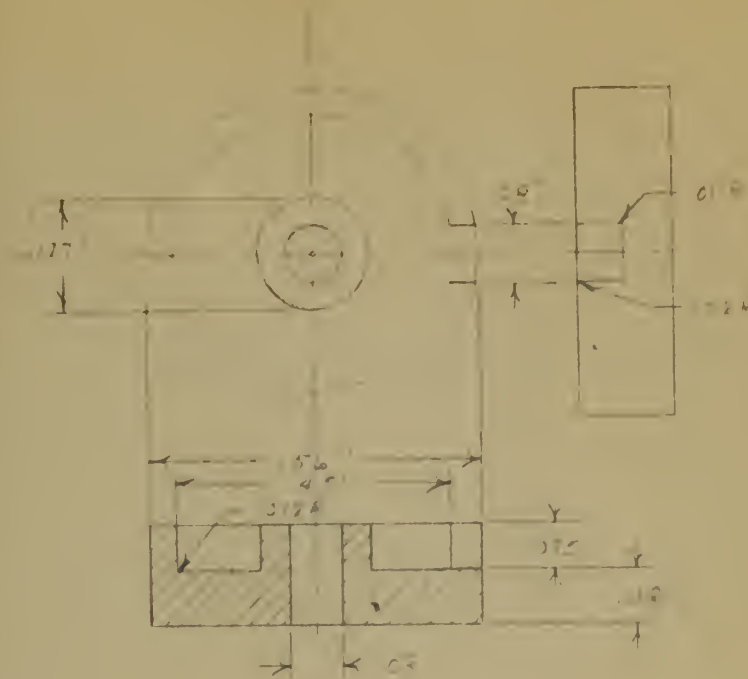
Channel (D)	Channel (E)	Channel (F)	Channel (G)	Channel (H)
V ₄₃	V ₄₄ (X-5)	V ₄₅ (X-43)	V ₄₀	V ₄₆ (X-40)
V ₁₄	V ₁₈	V ₂₂	V ₂₆	V ₃₀
V ₁₅ (X-14)	V ₁₉ (X-18)	V ₂₃ (X-22)	V ₂₇ (X-26)	V ₃₁ (X-30)
V ₁₆	V ₂₀	V ₂₄	V ₂₈	V ₃₂
V ₁₇	V ₂₁ (X-17)	V ₂₅	V ₂₉ (X-25)	V ₃₃
R ₇₅	R ₈₉	R ₁₀₃	R ₁₁₇	R ₁₃₁
R ₇₆	R ₉₀	R ₁₀₄	R ₁₁₈	R ₁₃₂
R ₇₇	R ₉₁	R ₁₀₅	R ₁₁₉	R ₁₃₃
R ₇₈	R ₉₂	R ₁₀₆	R ₁₂₀	R ₁₃₄
R ₈₀	R ₉₄	R ₁₀₈	R ₁₂₂	R ₁₃₆
R ₇	R ₉	R ₁₀	R ₁₁	R ₁₂
R ₈₁	R ₉₅	R ₁₀₉	R ₁₂₃	R ₁₃₇
R ₈₂	R ₉₆	R ₁₁₀	R ₁₂₄	R ₁₃₈
R ₈₃	R ₉₇	R ₁₁₁	R ₁₂₅	R ₁₃₉
R ₈₄	R ₉₈	R ₁₁₂	R ₁₂₆	R ₁₄₀
R ₈₅	R ₉₉	R ₁₁₃	R ₁₂₇	R ₁₄₁
R ₈₆	R ₁₀₀	R ₁₁₄	R ₁₂₈	R ₁₄₂
R ₈₇	R ₁₀₁	R ₁₁₅	R ₁₂₉	R ₁₄₃
R ₈₈	R ₁₀₂	R ₁₁₆	R ₁₃₀	R ₁₄₄
R ₇₉	R ₉₃	R ₁₀₇	R ₁₂₁	R ₁₃₅
C ₄₅	C ₅₃	C ₆₁	C ₆₉	C ₇₇
C ₄₆	C ₅₄	C ₆₂	C ₇₀	C ₇₈
C ₄₇	C ₅₅	C ₆₃	C ₇₁	C ₇₉

Channel (D)	Channel (E)	Channel (F)	Channel (G)	Channel (H)
C ₄₈	C ₅₆	C ₆₄	C ₇₂	C ₈₀
C ₄₉	C ₅₇	C ₆₅	C ₇₃	C ₈₁
C ₅₀	C ₅₈	C ₆₆	C ₇₄	C ₈₂
C ₅₁	C ₅₉	C ₆₇	C ₇₅	C ₈₃
C ₅₂	C ₆₀	C ₆₈	C ₇₆	C ₈₄
T ₄	T ₅	T ₆	T ₇	T ₈
Y ₇	Y ₈	Y ₉	Y ₁₀	Y ₁₁
Y ₁₂	Y ₁₃	Y ₁₄	Y ₁₅	Y ₁₆
SW ₃	SW ₄	SW ₅	SW ₆	SW ₇

Cross reference TABLE for pulse generation channels (D) through (H).

(1) 1900-1901	(2) 1901-1902	(3) 1902-1903	(4) 1903-1904	(5) 1904-1905
100	100	100	100	100
100	100	100	100	100
100	100	100	100	100
100	100	100	100	100
100	100	100	100	100
100	100	100	100	100
100	100	100	100	100
100	100	100	100	100
100	100	100	100	100

THESE FIGURES ARE THE TOTALS OF THE FIGURES IN THE TABLES ON THE PRECEDING PAGES.

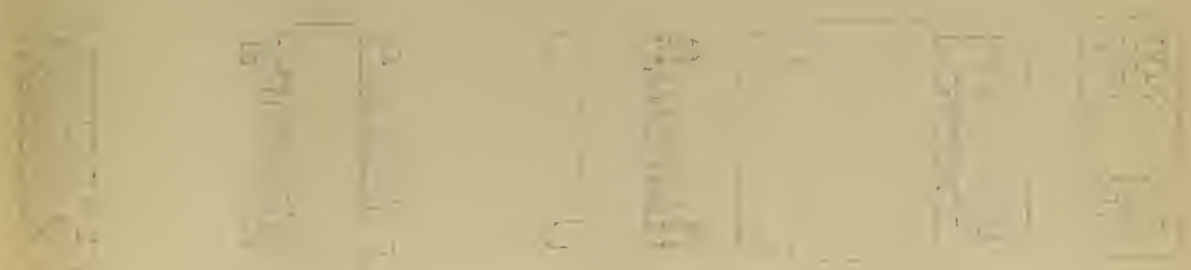


Dimensions: Same as Pat. 2,154,754, Type 7F-54, modified by the FEATHERBUSH Corporation.

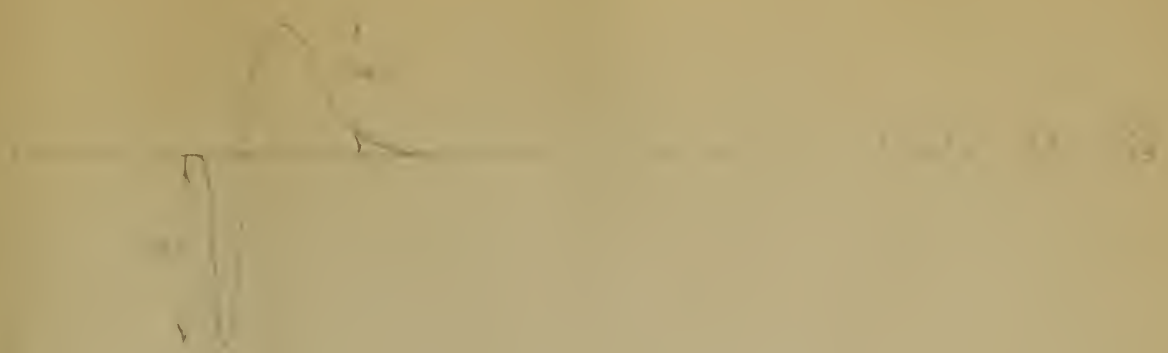


Spinal Cord Section			
Section	Color	Texture	Notes
A	White	Smooth	Normal
B			
C	Gray	Slight	Flange
D	Gray	Dark	Large flange
E			
F	Gray	Dark	Large flange
G			
H	Gray	Dark	Large flange
I			
J			
K	Gray	Dark	Large flange
L			
M	Gray	Dark	Large flange
N			
O	Gray	Dark	Large flange
P			
Q	Gray	Dark	Large flange
R			
S	Gray	Dark	Large flange
T			
U	Gray	Dark	Large flange
V			
W	Gray	Dark	Large flange
X			
Y	Gray	Dark	Large flange
Z			

The results of the H. and F. plates is the same as above, showing a slight degree of inflammation in the lower part of the spinal cord.



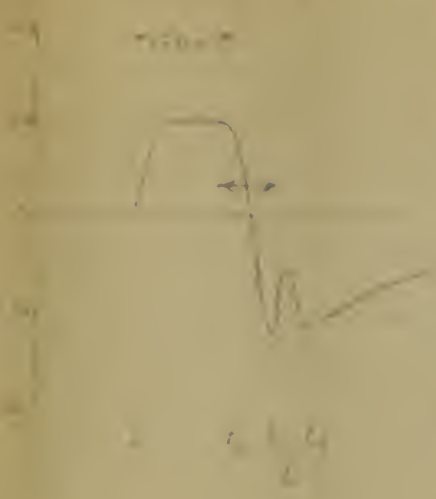




Hand-drawn graph showing a curve starting at the origin, peaking, and then decaying towards the x-axis. The y-axis is labeled with '1' and '2'.

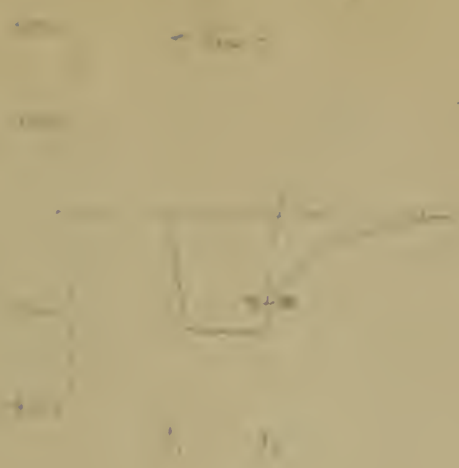
$P_{10} = 10$

$\omega = 0$



$P_{10} = 10$

$\omega = 1$



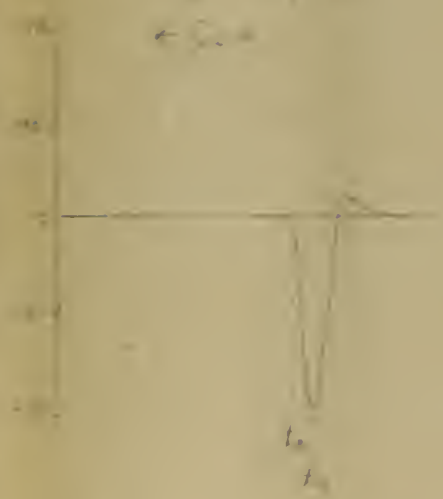
$P_{10} = 10$

$\omega = 2$



$P_{10} = 10$

$\omega = 3$



$P_{10} = 10$

$\omega = 4$

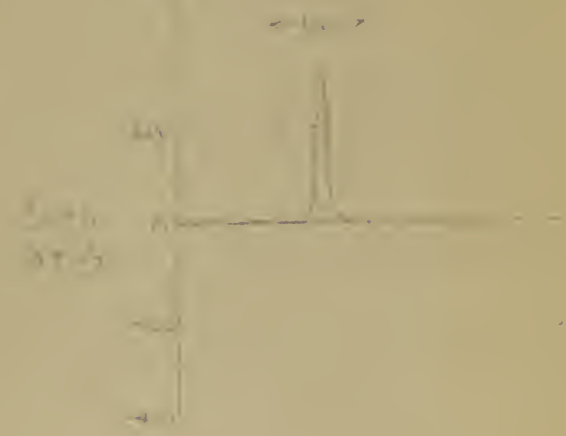
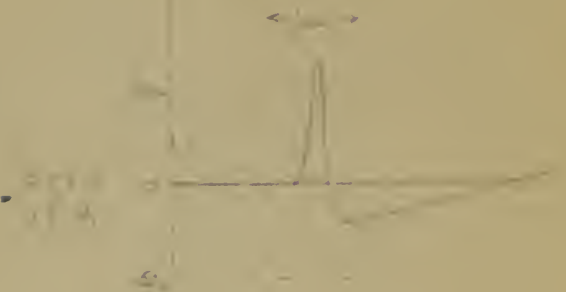
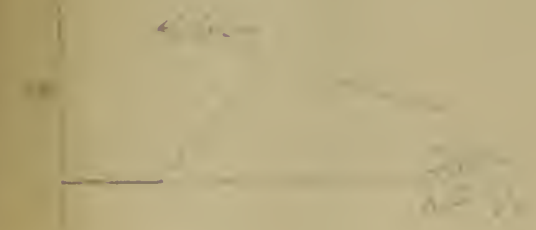
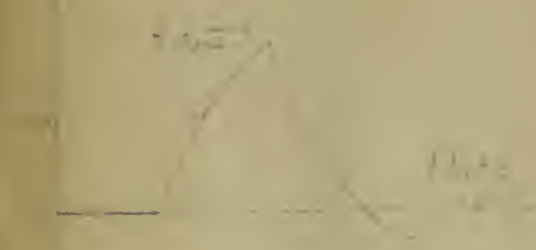
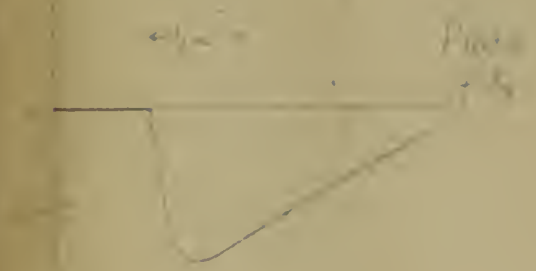


$P_{10} = 10$

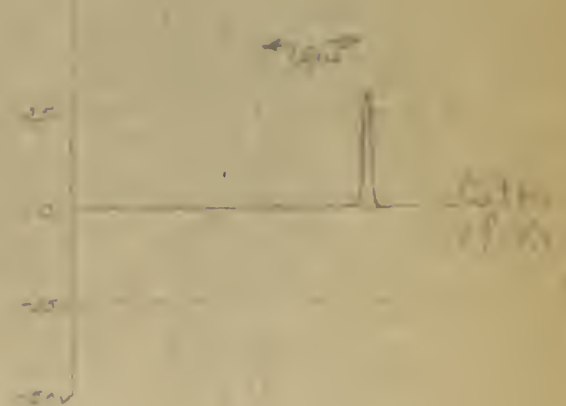
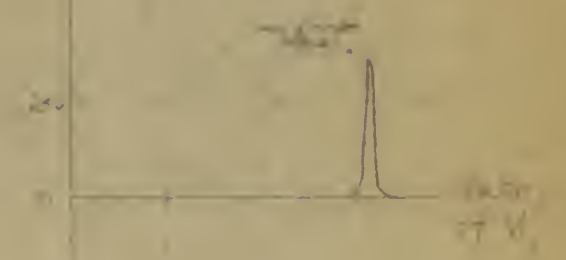
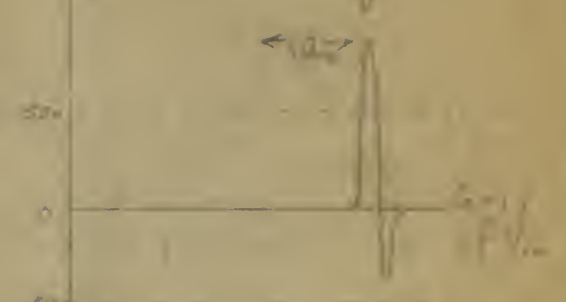
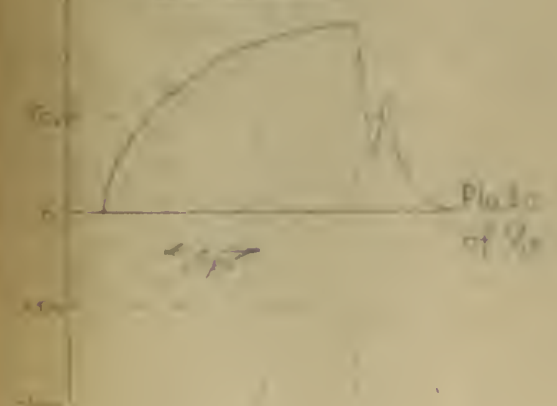
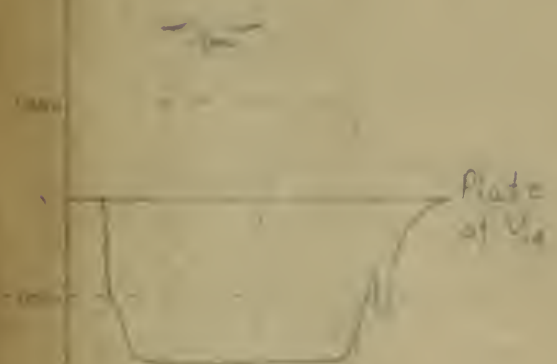
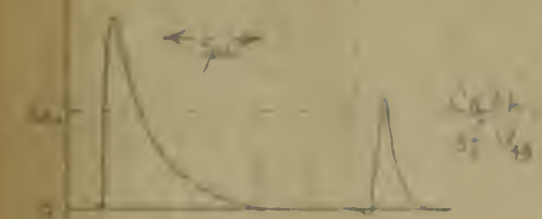
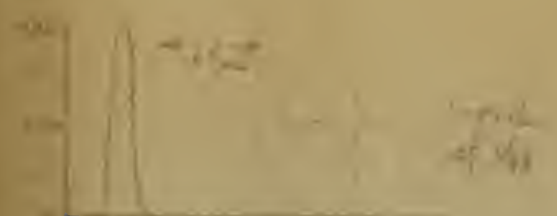
$\omega = 5$



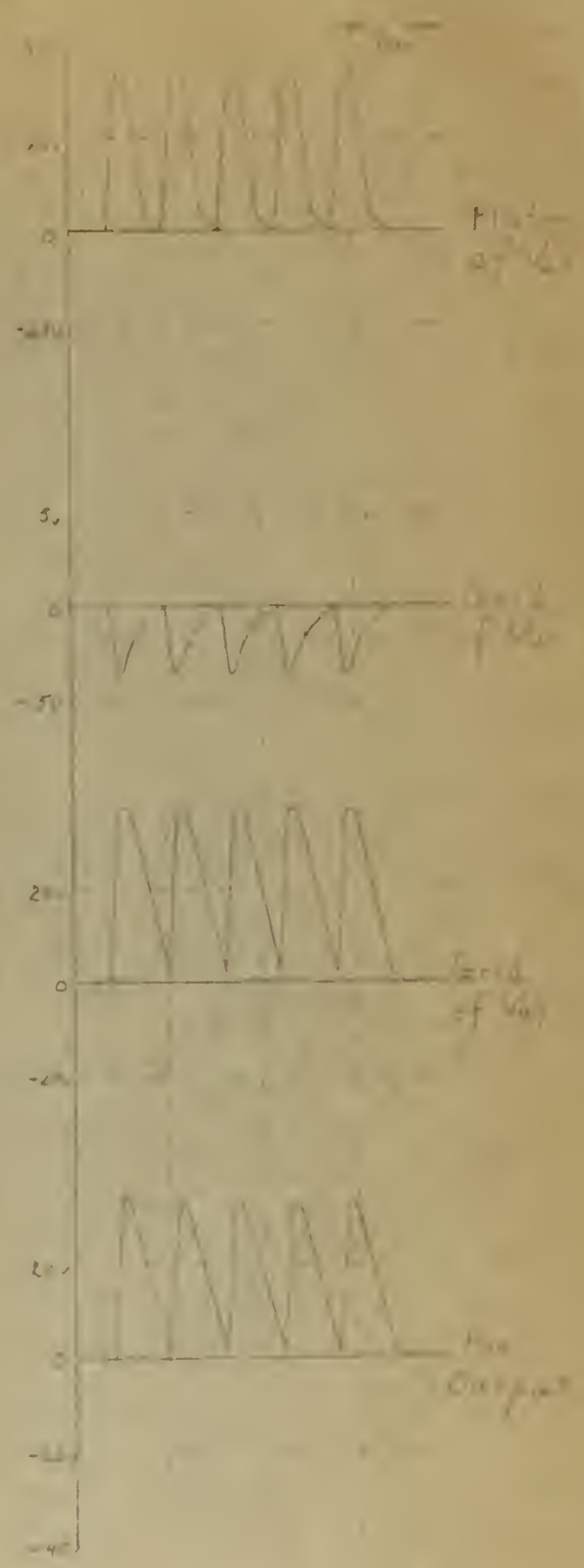
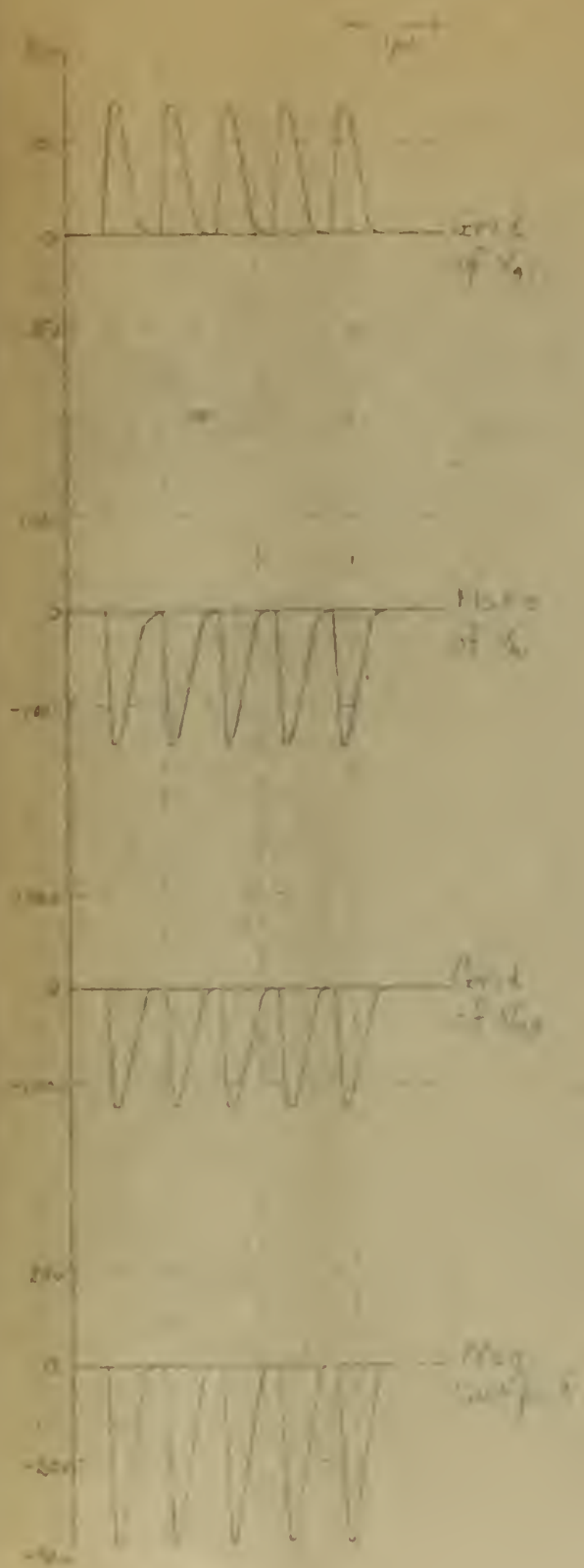
Waveform for $P_{10} = 10$



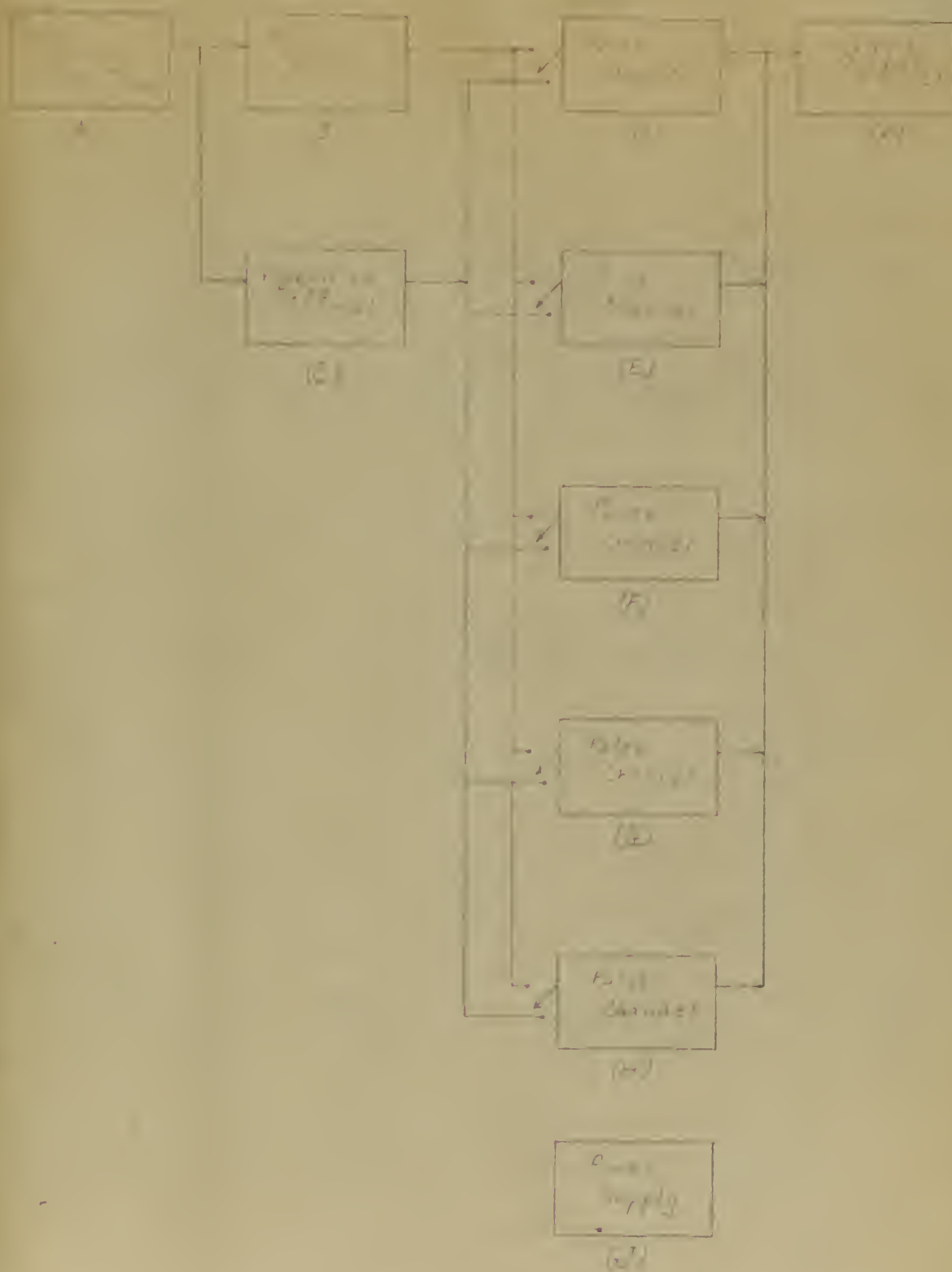
Waveforms for Channel (2)



Waveform in Channel (2) through (8)

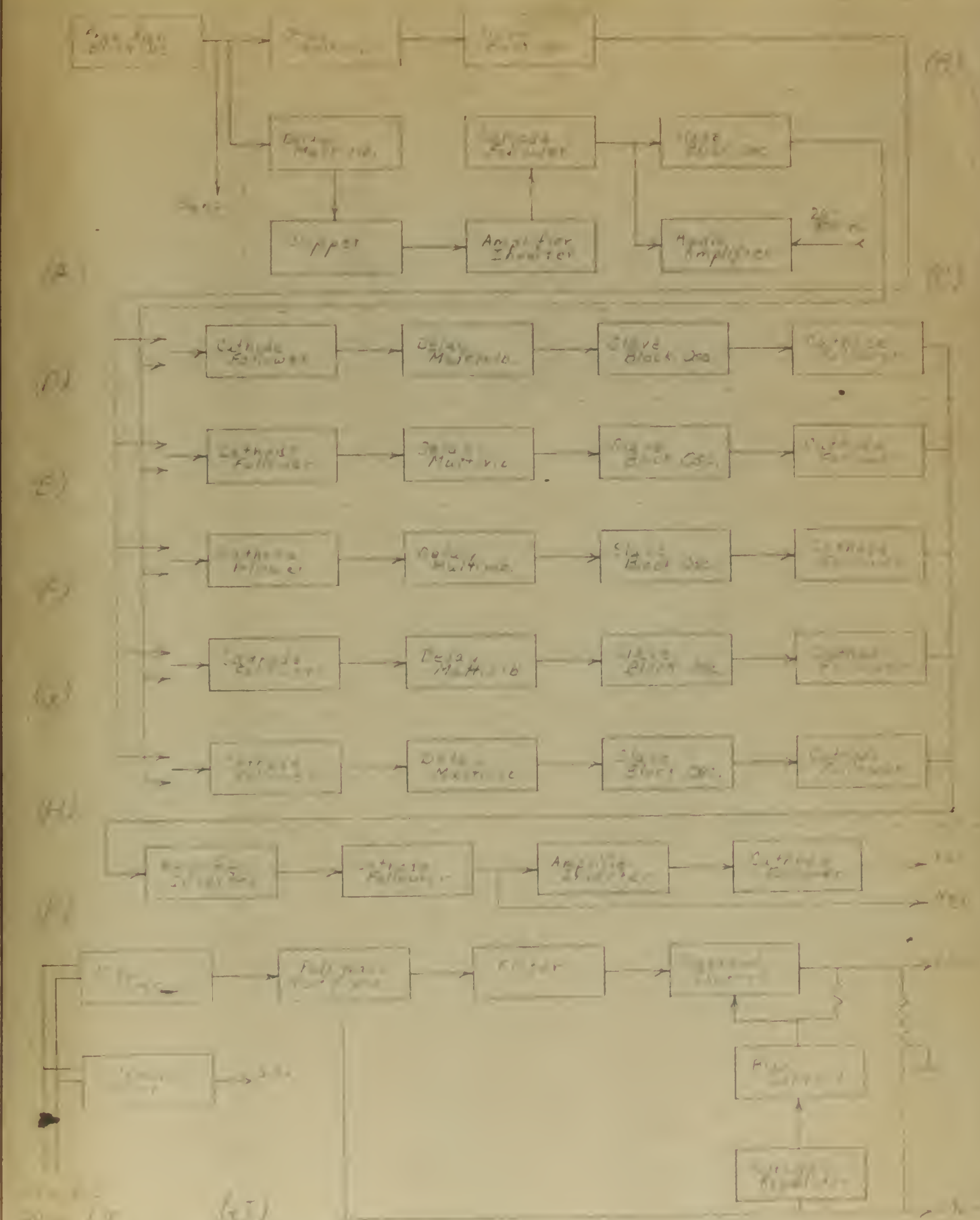


Waveform for Channel (K).



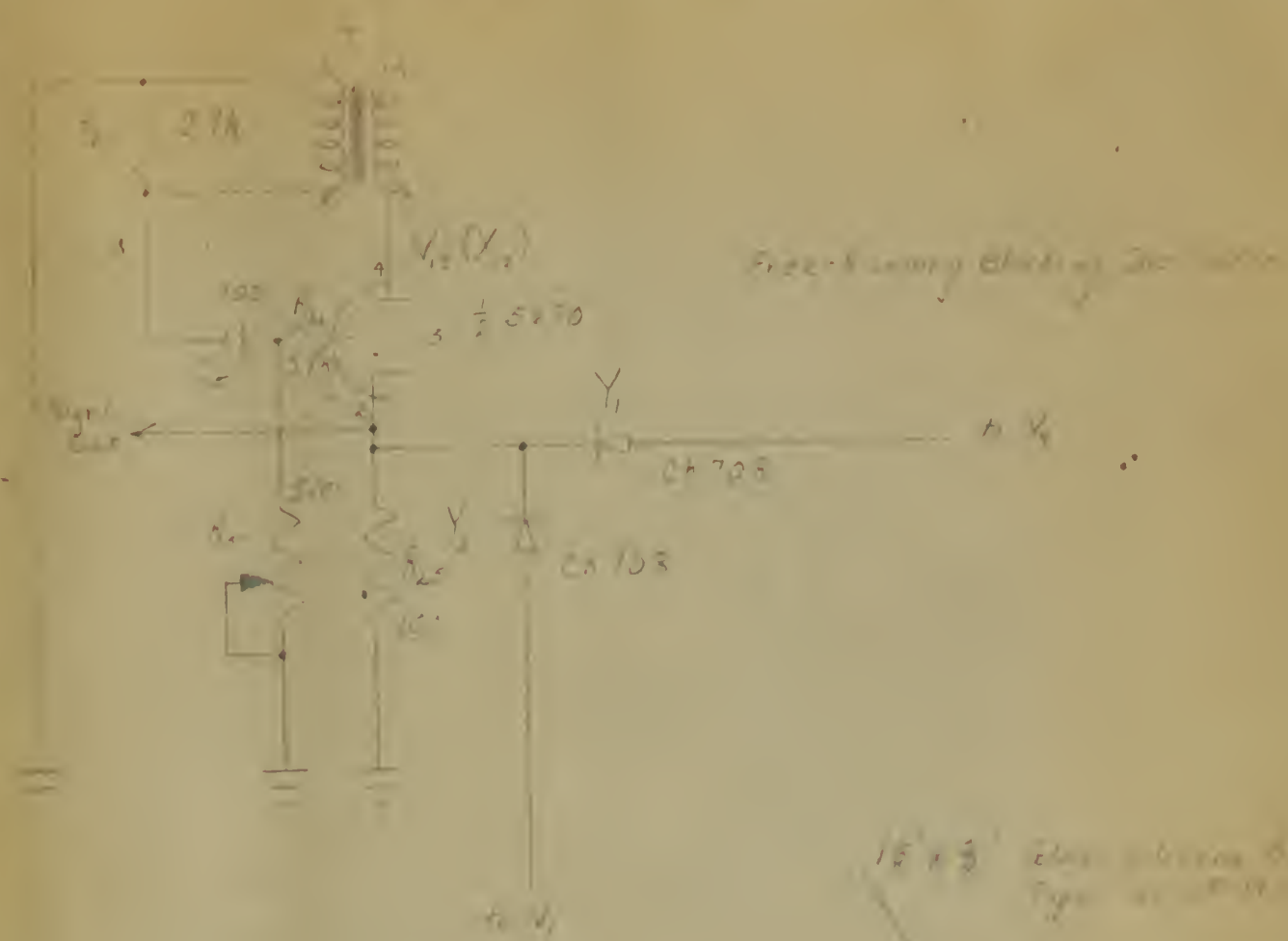
MAR 3 1952

SCALE	TITLE	MELPAR, INC.	
DRAWN	Simple Block Diagram	ALEXANDRIA VA	
APPROVED	MATERIAL	PROJECT NO	EA 1
DATE 2-27-52	FINISH	1052	



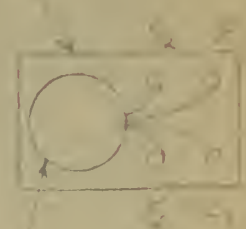
SCALE	TITLE	MELPAR, INC.	
DRAWN	Simplex Block Diagram	ALEXANDRIA, VA	
APPROVED	MATERIAL	PROJECT NO	EA 2 MAR 3 1952
DATE	FINISH	# 155	

12-20

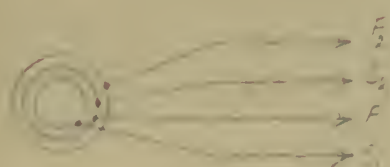


T₁: 12-20-300 primary
 12-20-300 secondary
 #28 552 wire
 Mandrel for 20

1/2 x 3/4 Glass plate 1/2" thick
 Type 40-10-10-10

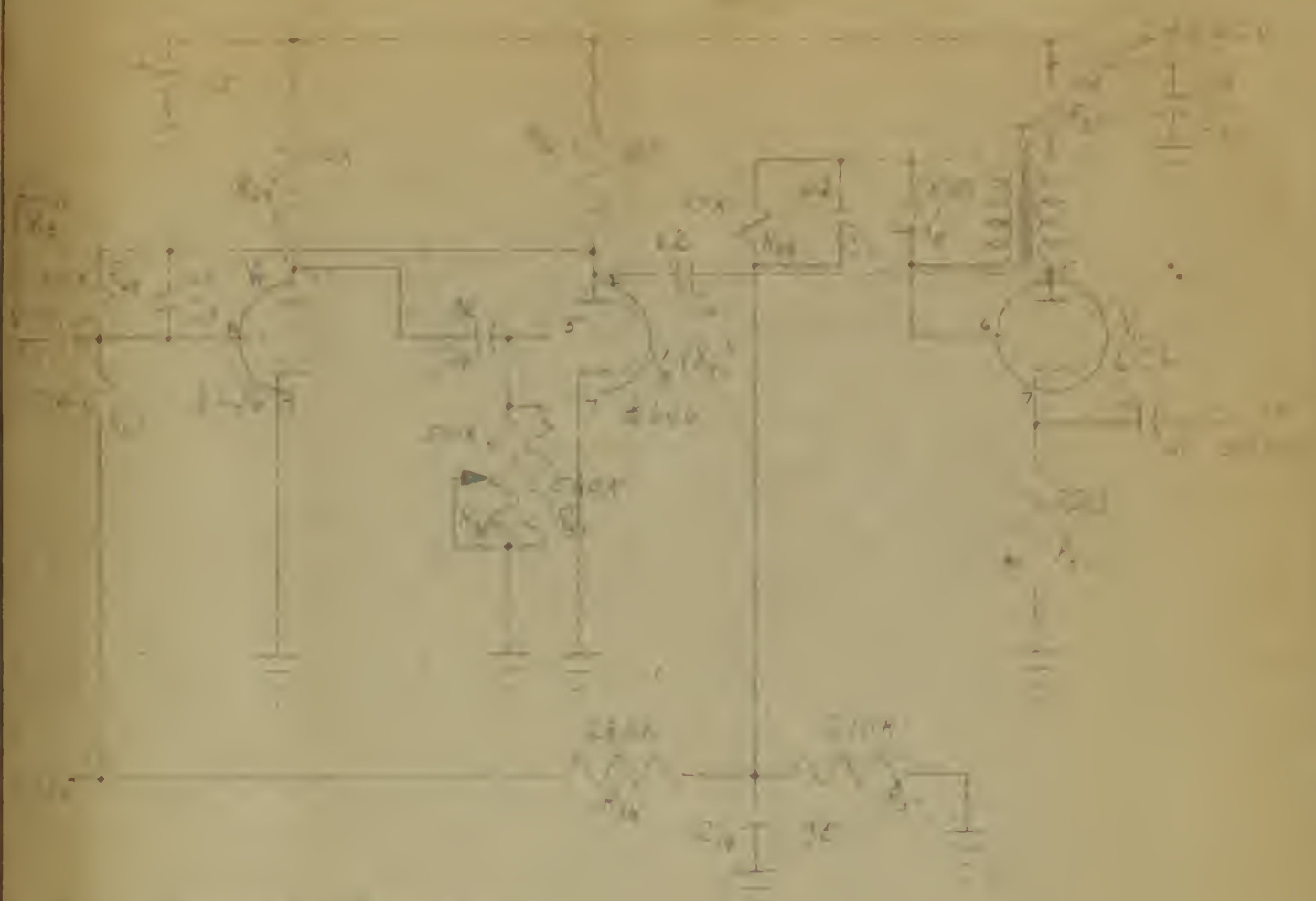


Transformer 1/2" x 3/4" x 1/2"
 Type 40-10-10-10



MAR 7 1952

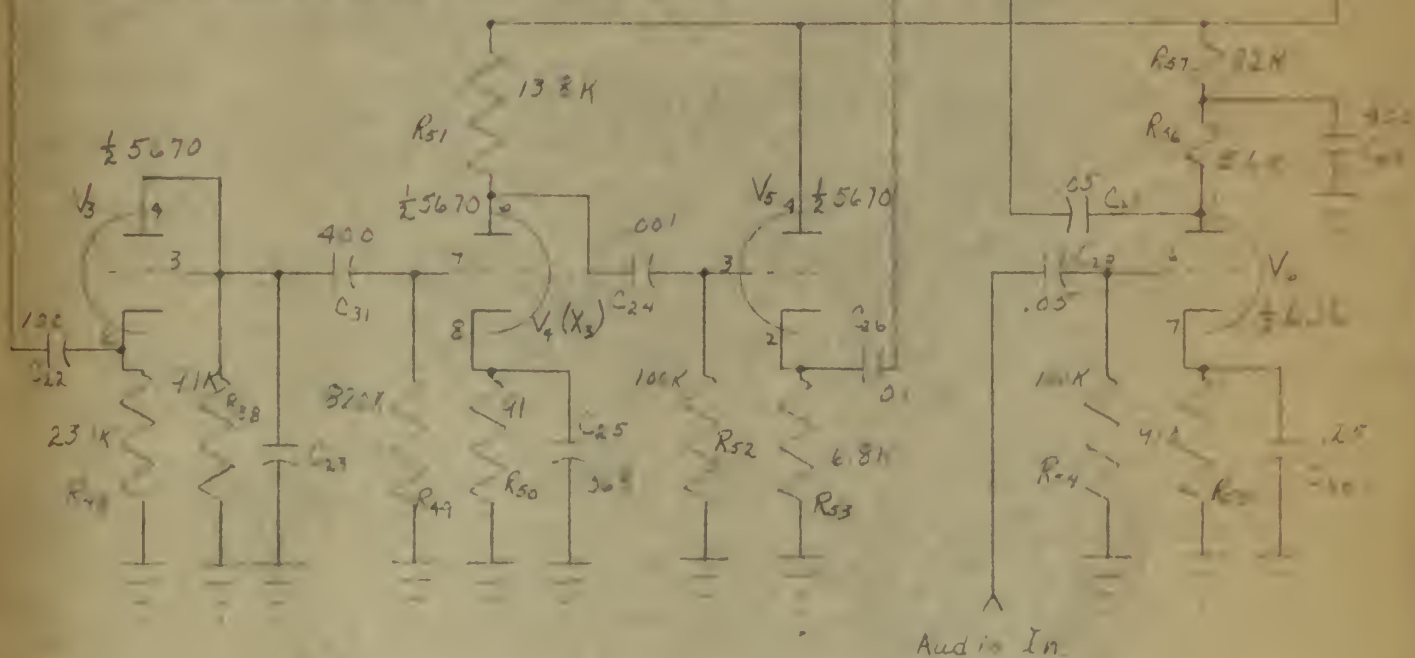
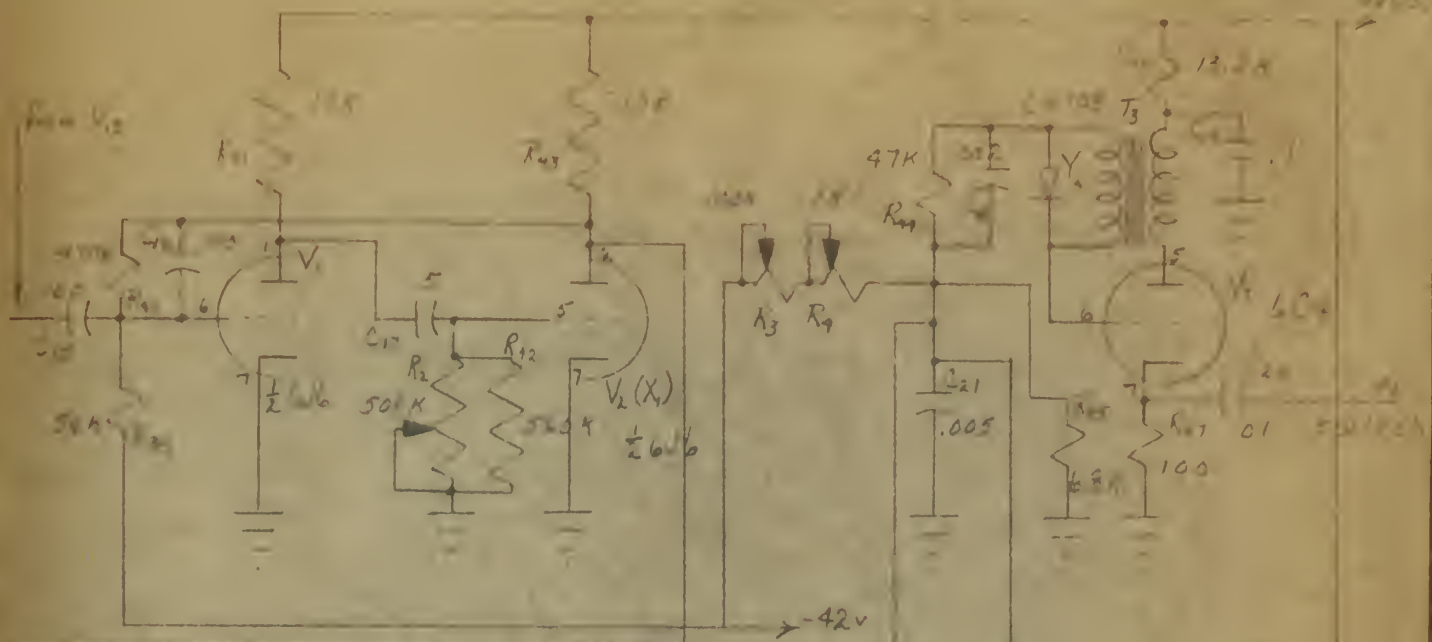
SCALE	TITLE	MELPAR, INC.	
DRAWN	Channel (A) of Modulator	ALEXANDRIA VA	
APPROVED	MATERIAL	PROJECT NO	EA 5
DATE 5-2-52	FINISH	# 1155	



310 240 100 50
 200 240 30

MAR 7 1952

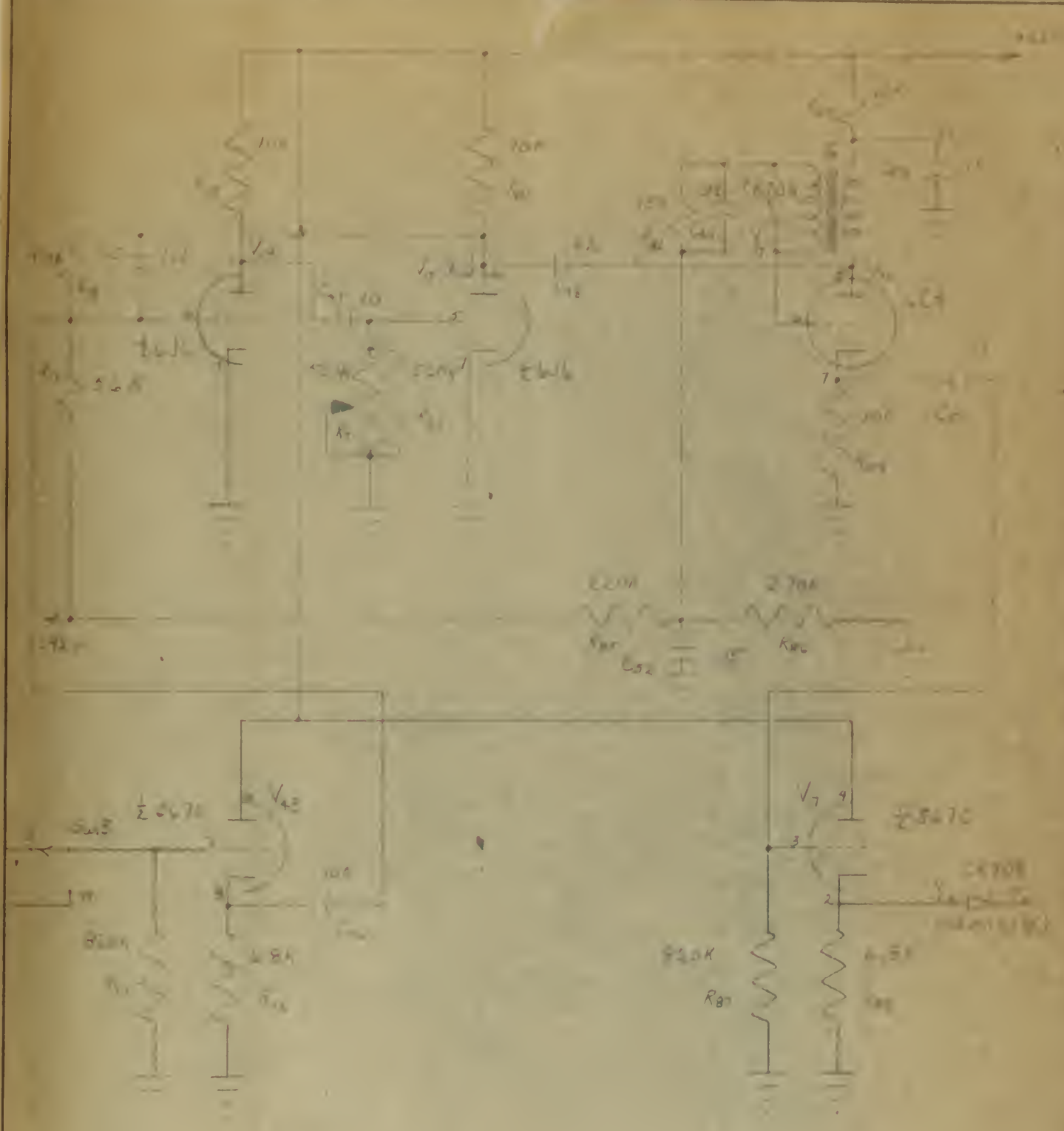
SCALE	TITLE	MELPAR, INC.	
DRAWN		ALEXANDRIA VA	
APPROVED	MATERIAL	PROJECT NO	EA
DATE	FINISH		



C_{23} is the short and stray capacitance across R_{23} to ground.

MAR 4 1952

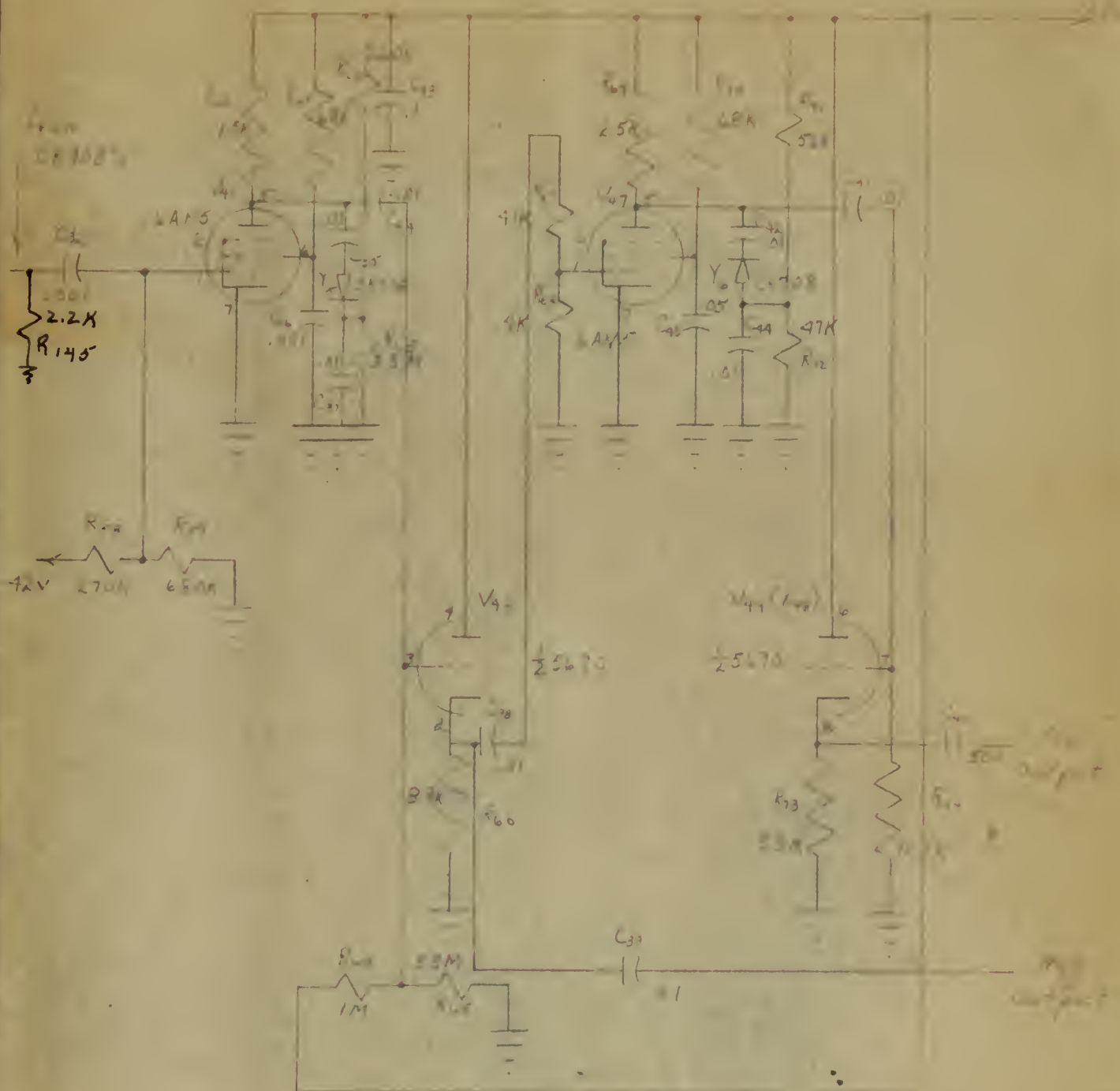
SCALE	TITLE	MELPAR, INC.	
DRAWN <i>KV</i>	Channel (C) of Modulator	ALEXANDRIA VA	
APPROVED	MATERIAL	PROJECT NO	EA 5
DATE <i>March 1952</i>	FINISH	<i>#1153</i>	



See data for 7, in
EA 3

SCALE	TITLE	MELPAR, INC.	
DRAWN	Channel 101 Modulator	ALEXANDRIA, VA.	
APPROVED	MATERIAL	PROJECT NO.	EA 6
DATE	FINISH		





MAR 4 1952

SCALE	TITLE	MELPAR, INC.	
DRAWN	Channel (K) of Modulator	ALEXANDRIA VA	
APPROVED	MATERIAL	PROJECT NO	EA 7
DATE 4/1/52	FINISH	# 1153	

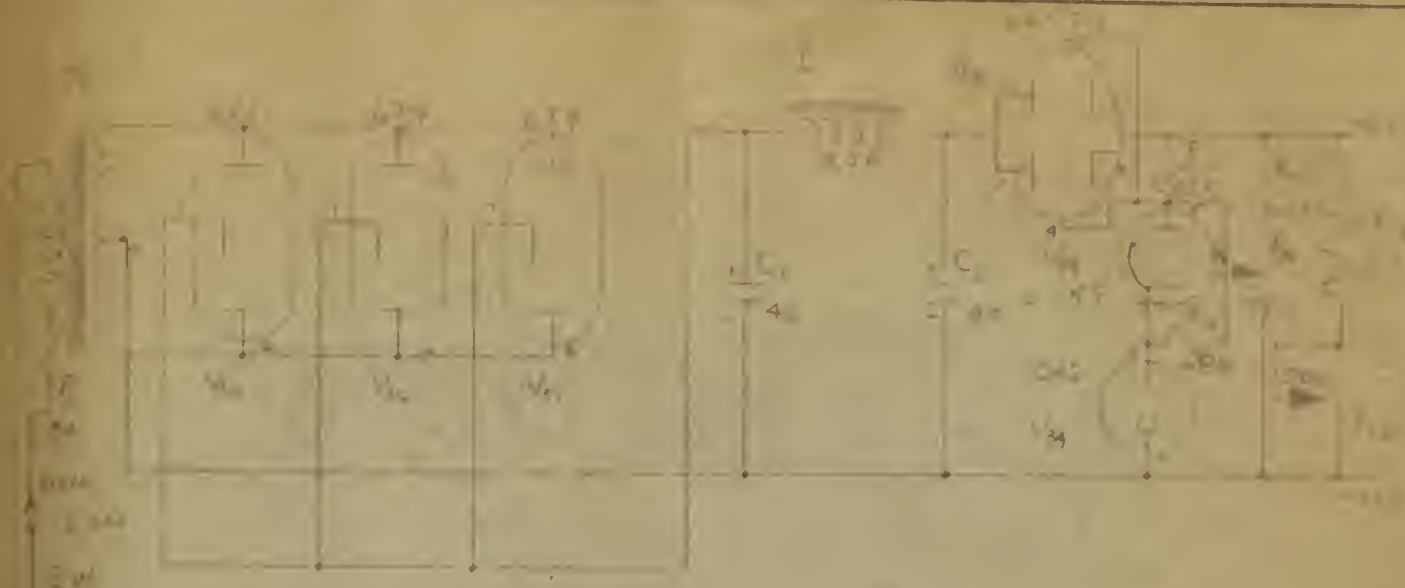


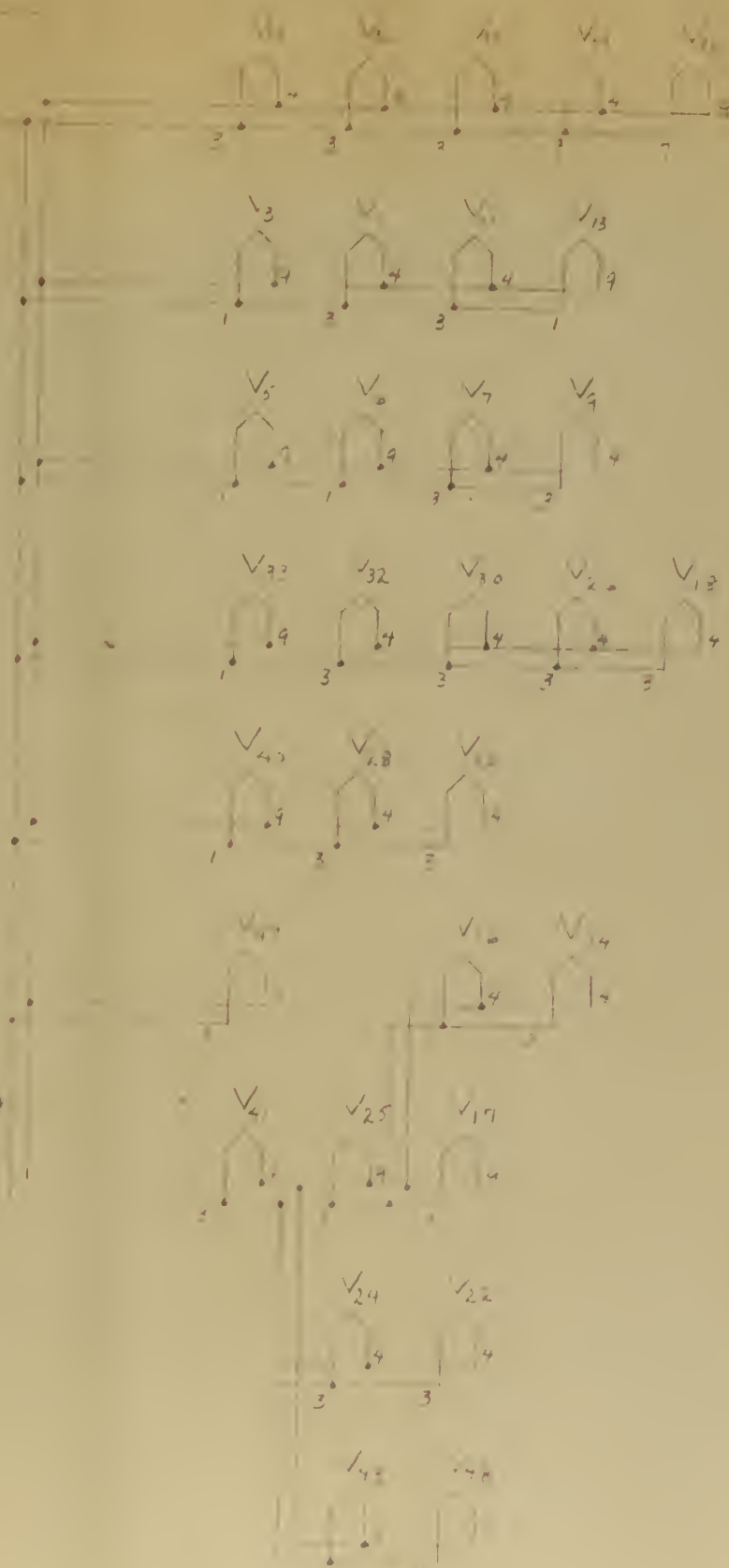
Fig. 10 is a circuit diagram
tapped with a 1000 250
diode



1. Standard # 40/40 7000 25 2000
2. Standard # 40/40 600 15 1000

MAR 11 1952

SCALE	TITLE	MELPAR, INC.	
DRAWN	40/40 Modulator	ALEXANDRIA VA	
APPROVED	MATERIAL	PROJECT NO	EA
DATE	FINISH	5-15-52	



MAR 11 1952

SCALE	TITLE	MELPAR, INC.	
DRAWN		ALEXANDRIA VA	
APPROVED	MATERIAL	PROJECT NO	EA 9
DATE	FINISH	# 1155	

B

1. UN
1. SPE

DECIMALS ±
FRACTIONS ±

COMMERCIAL PUBLISHED TOLERA
TO SIZES OF BAR, ROD, WIRE

CHANGE:

Fig 1

Fig 2

Fig 3

Fig 4

Fig 5



Fig 6

Fig 7

Fig 8

Fig 9

Fig 10

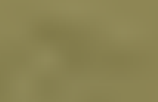


Fig 11

Fig 12

Fig 13

Fig 14

Fig 15

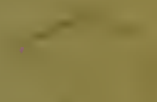


Fig 16

Fig 17

Fig 18

Fig 19

DE DIMALS ±
FRACTIONS ±
COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY
TO SIZES OF BAR, ROD, WIRE SHEET, TUBE ETC.

1/16" ±

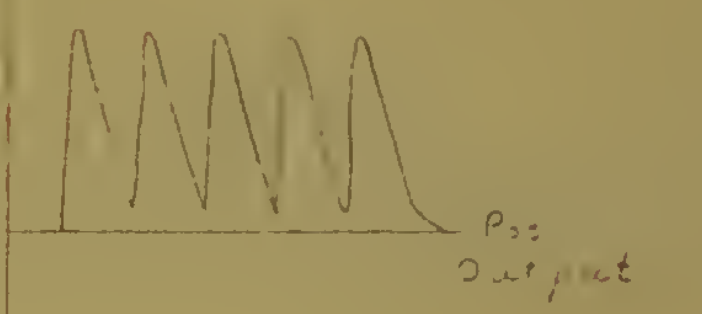
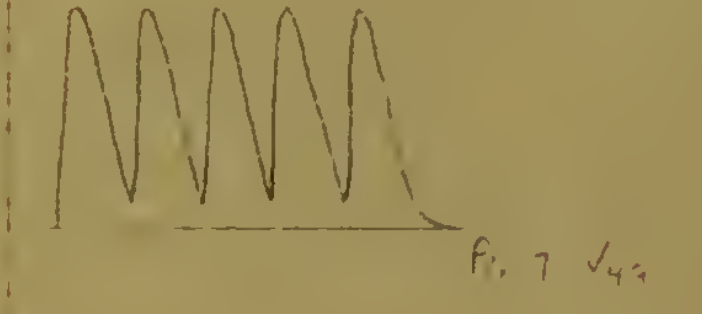
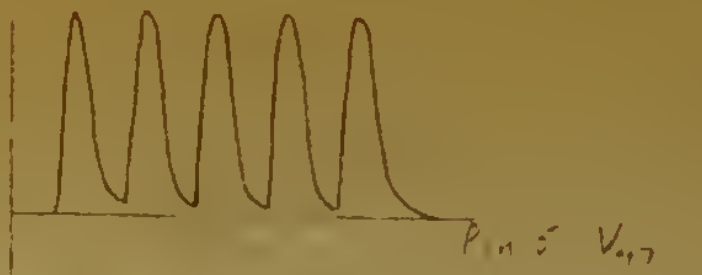
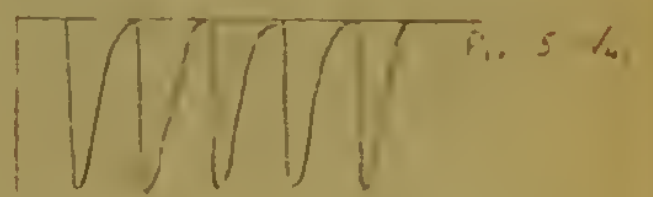
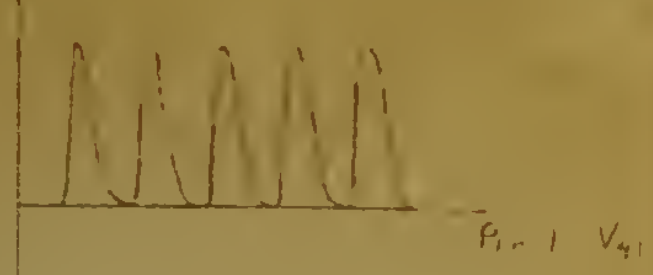
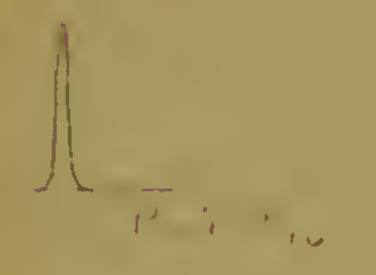
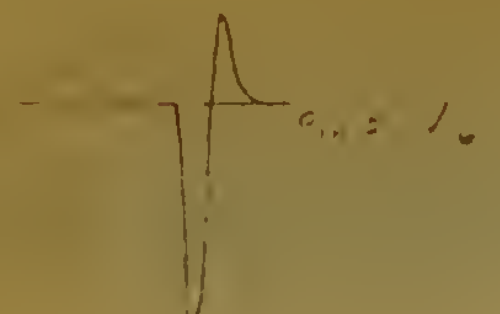
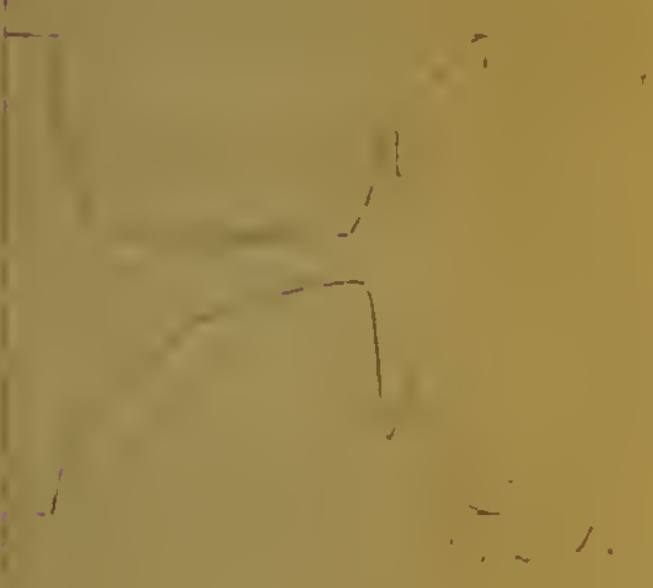
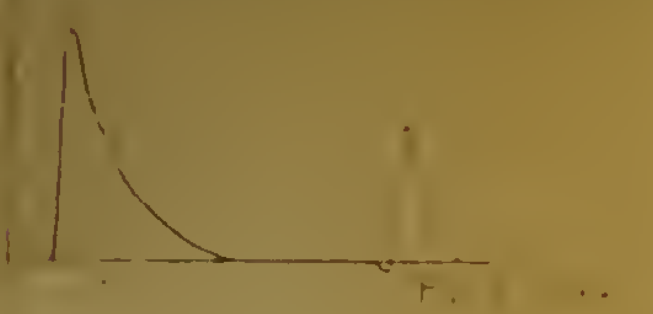
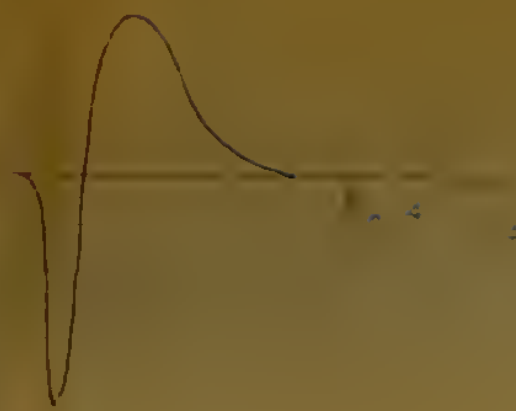
UNLESS OTHERWISE
SPECIFIED

REQ'D	DRAWING		ITEM	NAME		FIN.	ZONE	CIRCUIT SYMBOL
	USED ON	ASSY. DRWG.	QTY.	MELPAR, INC. ELECTRONICS ALEXANDRIA, VIRGINIA				
B				From 10,000 of 10,000 1,000				
				DRAWN BY	ENGINEER	MATERIAL		
				CHECKER	PROJ. ENGR.	FINISH		
				APPROVED	SCALE	B		CHG.

MAR 11 1964

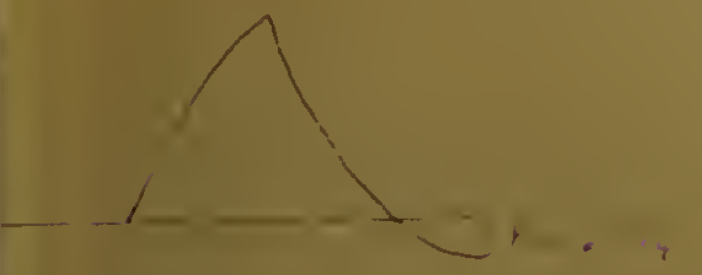


C



C

CHG



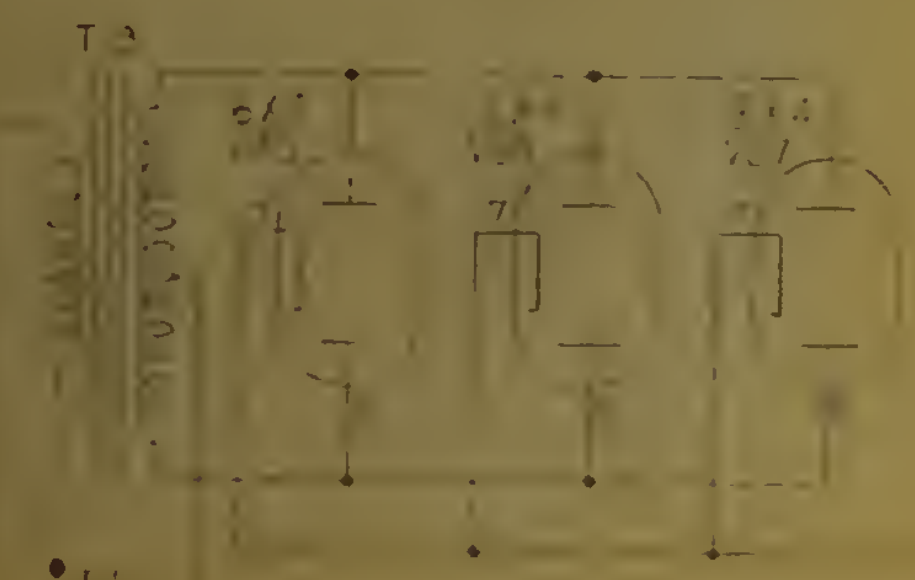
AN INCH 2
DECIMALS 2
FRACTIONS 2
COMMERCIAL PUBLISHING TOLERANCES SHALL APPLY
TO SIZE OF BAR, ROD, WIRE, SHEET, TUBE, ETC.

THIS DRAWING IS
FOR THE
THE RELATIONSHIP
RELATIONS

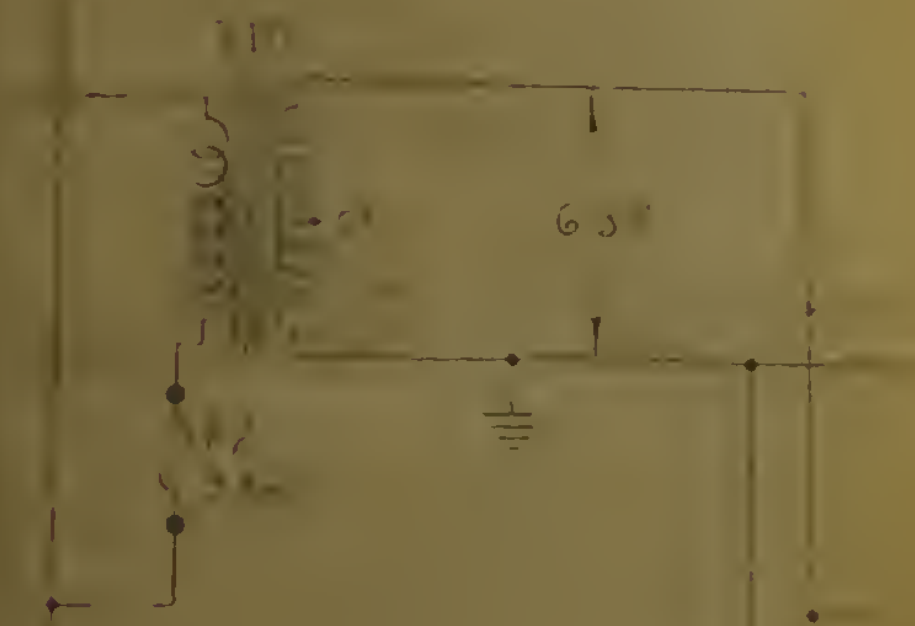
REFERENCE FOR A
DRAWING SHOWING AMPLITUDE AND
RELATIONS FOR INDIVIDUAL CHANNELS
REPORT

REQ'D	DRAWING		ITEM	NAME	FIN	ZONE	CIRCUIT SYMBOL
1	PROJECT NO.	NEXT ASSY	QTY	MELPAR, INC. ELECTRONICS ALEXANDRIA, VIRGINIA			
U				Modulator Waveforms.			
	DRAWING			DRAWN BY	ENGINEER	MATERIAL	
				CHECKER	PROJ. ENGR.	FINISH	
				APPROVED	SCALE	C	CHG.

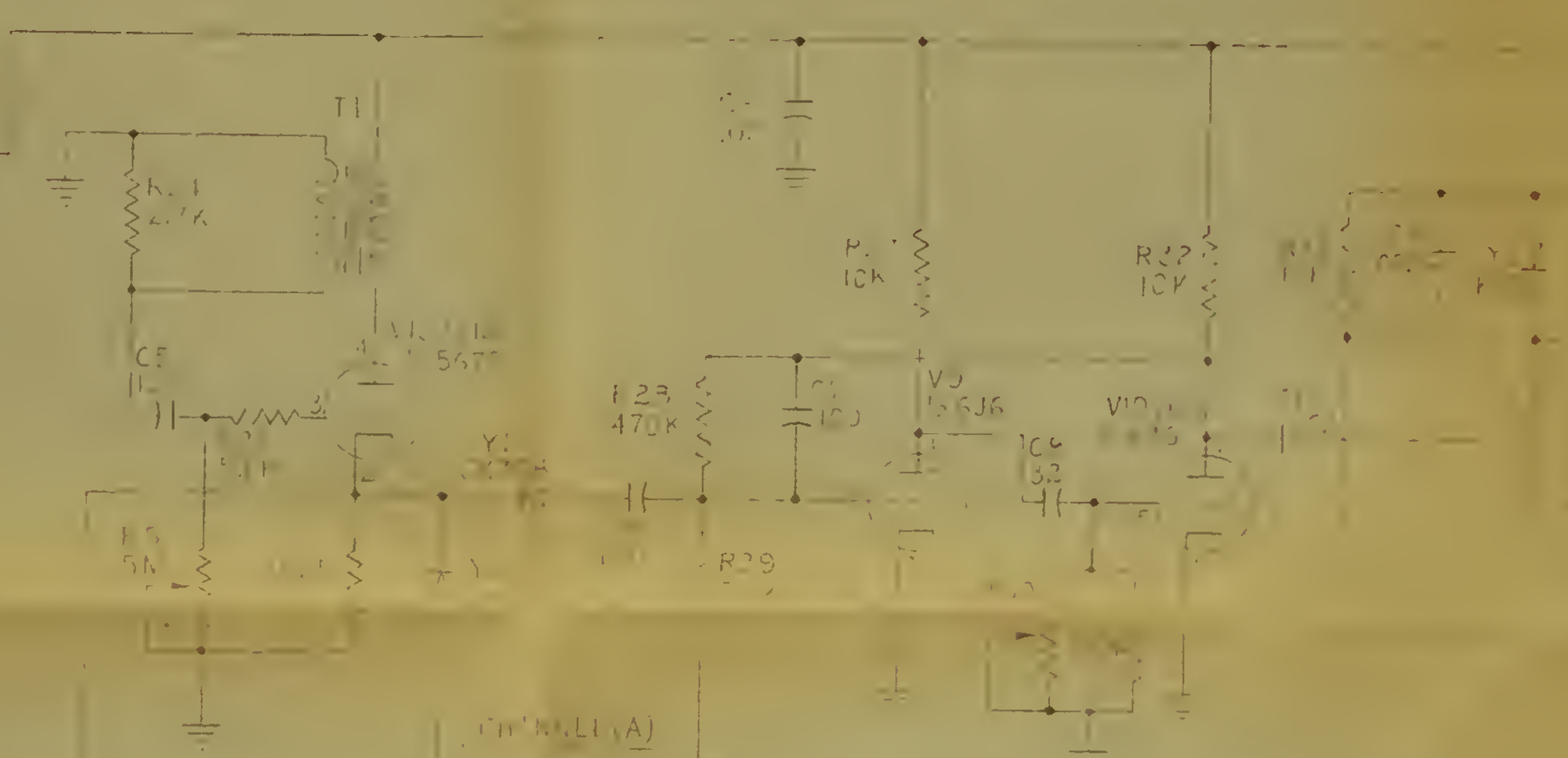
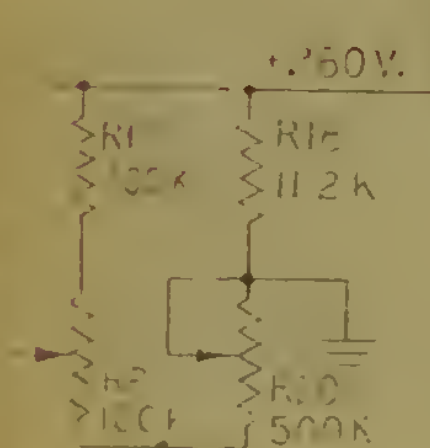
CONFIDENTIAL
SECURITY INFORMATION



POWER SUPPLY

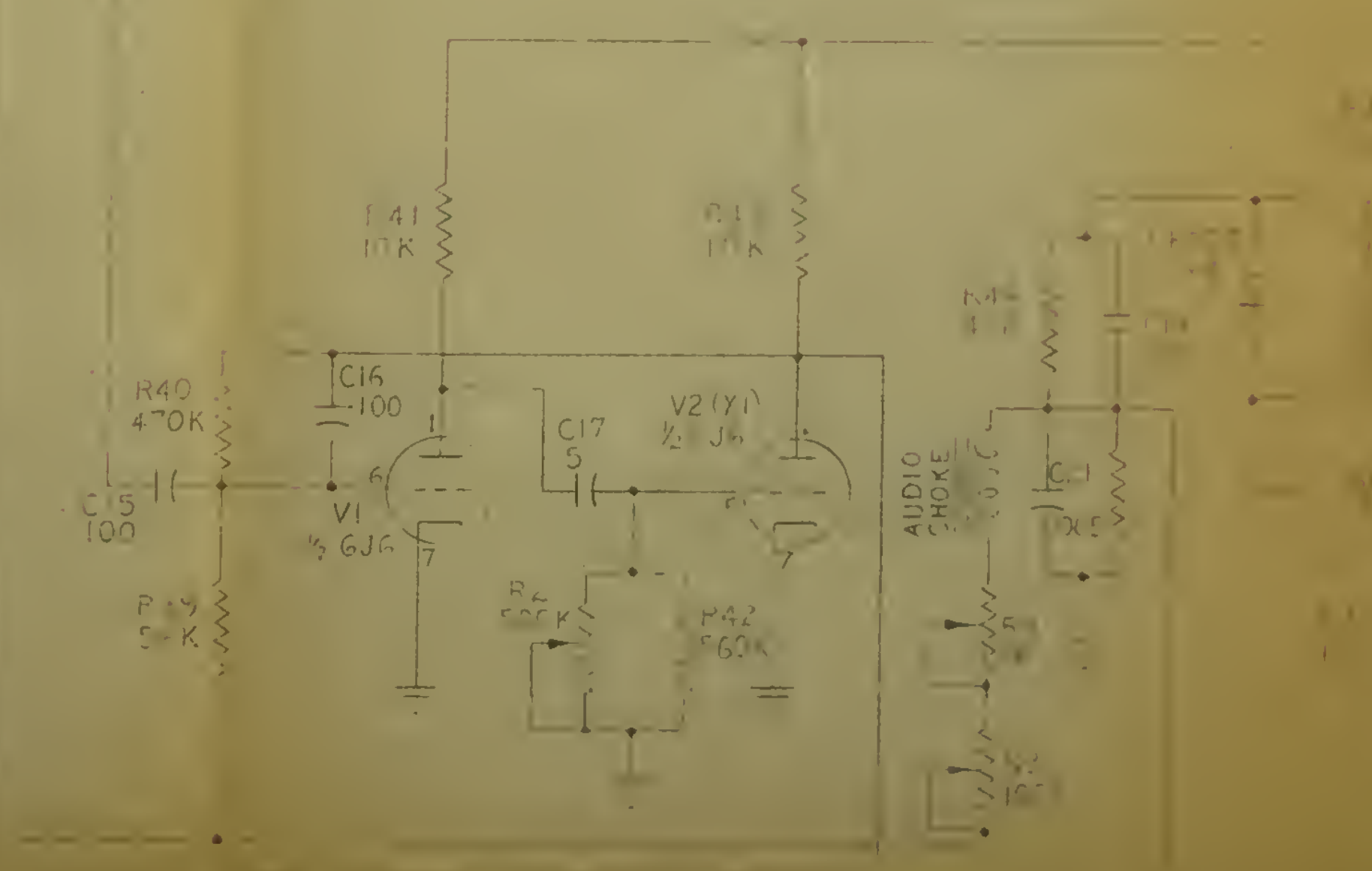


SW1

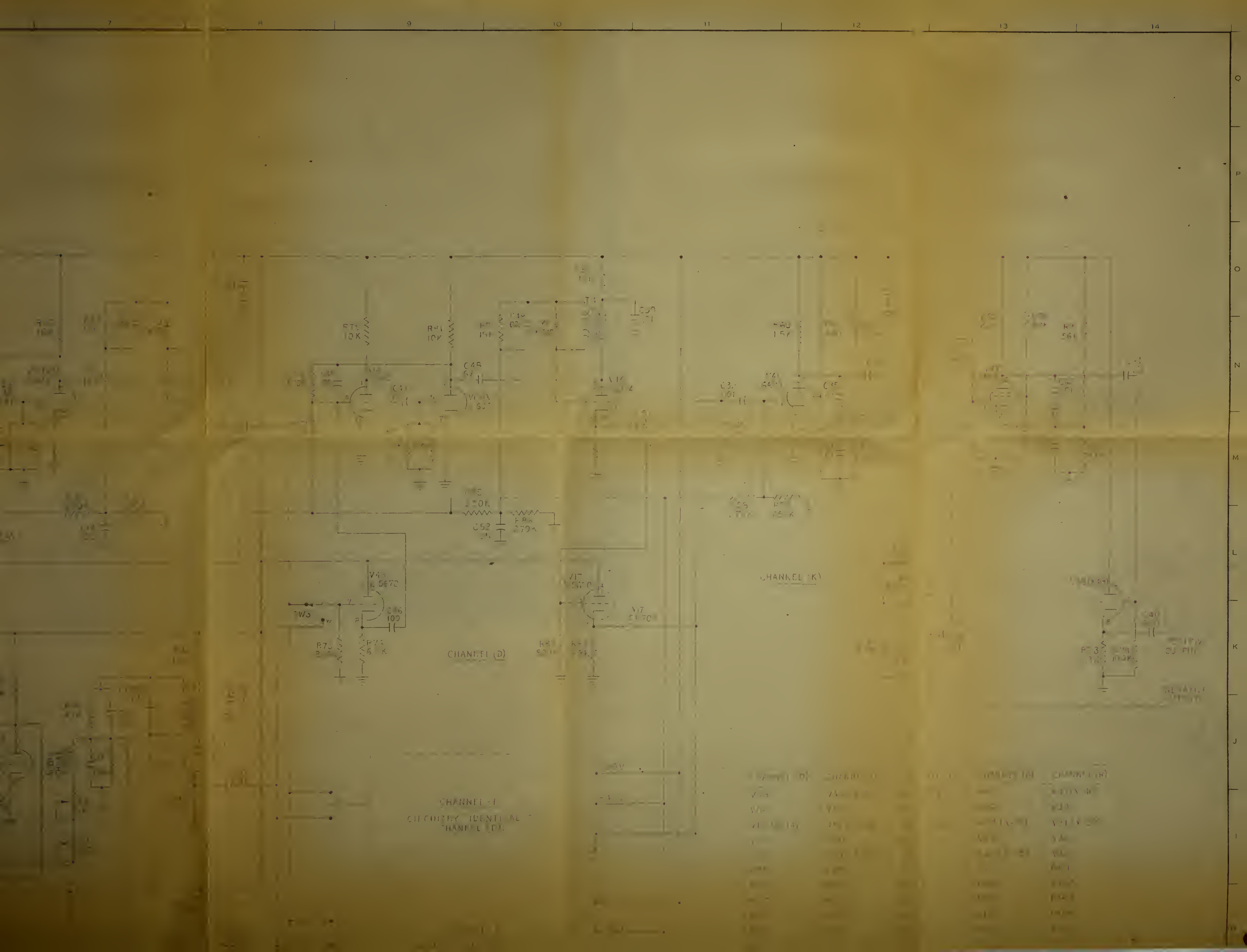


CHANNEL (A)

CHANNEL (B)



AUDIO



SYNC
CLT

AUDIO
IN

CHANNEL (C)

UNLESS OTHERWISE SPECIFIED
COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY
TO SIZE OF BAR ROD WIRE SHEET TUBE ETC

CHARLIE - H
CIRCUIT IDENTICAL TO
HARRIS (D).

4. V

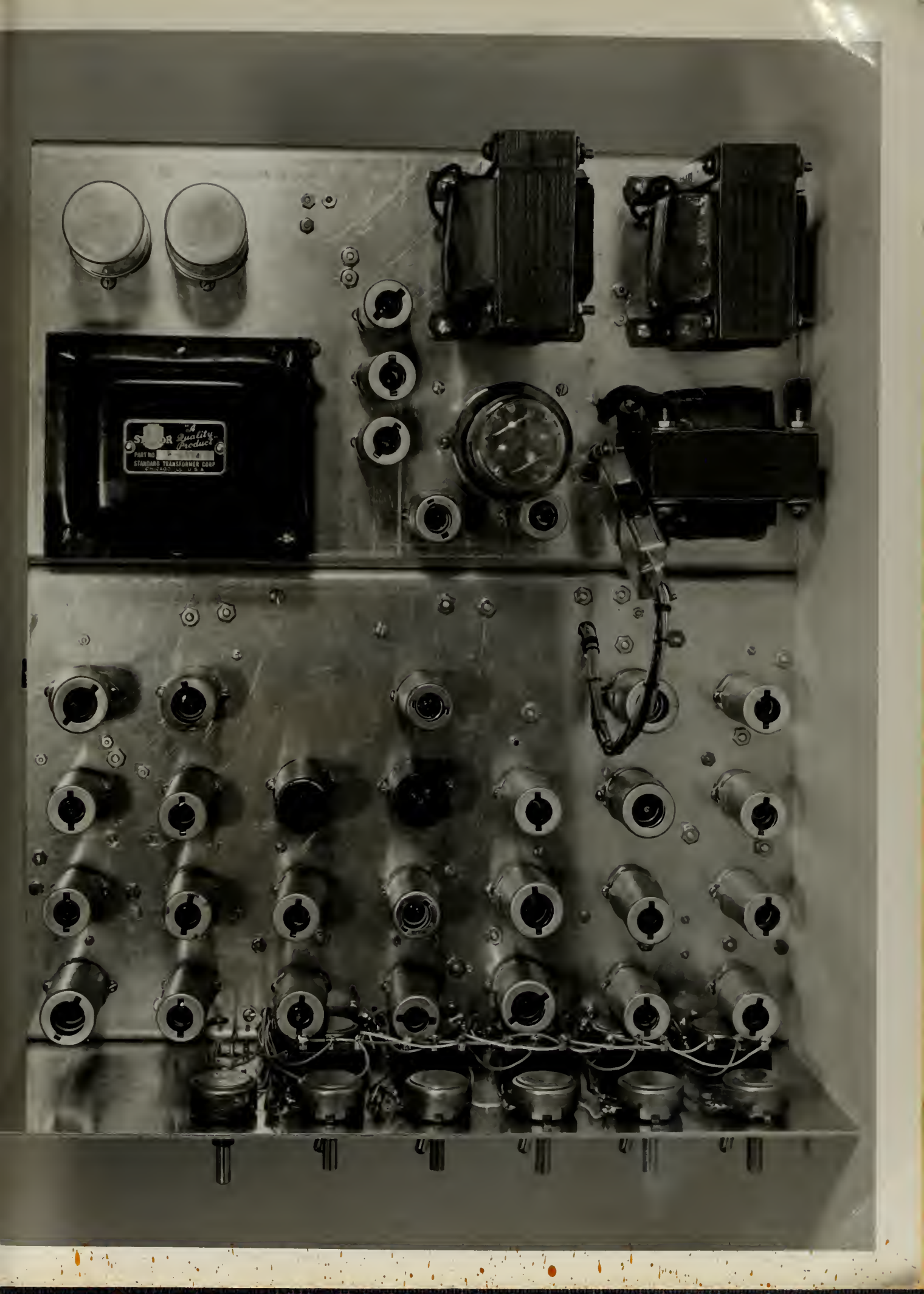
E 62

D

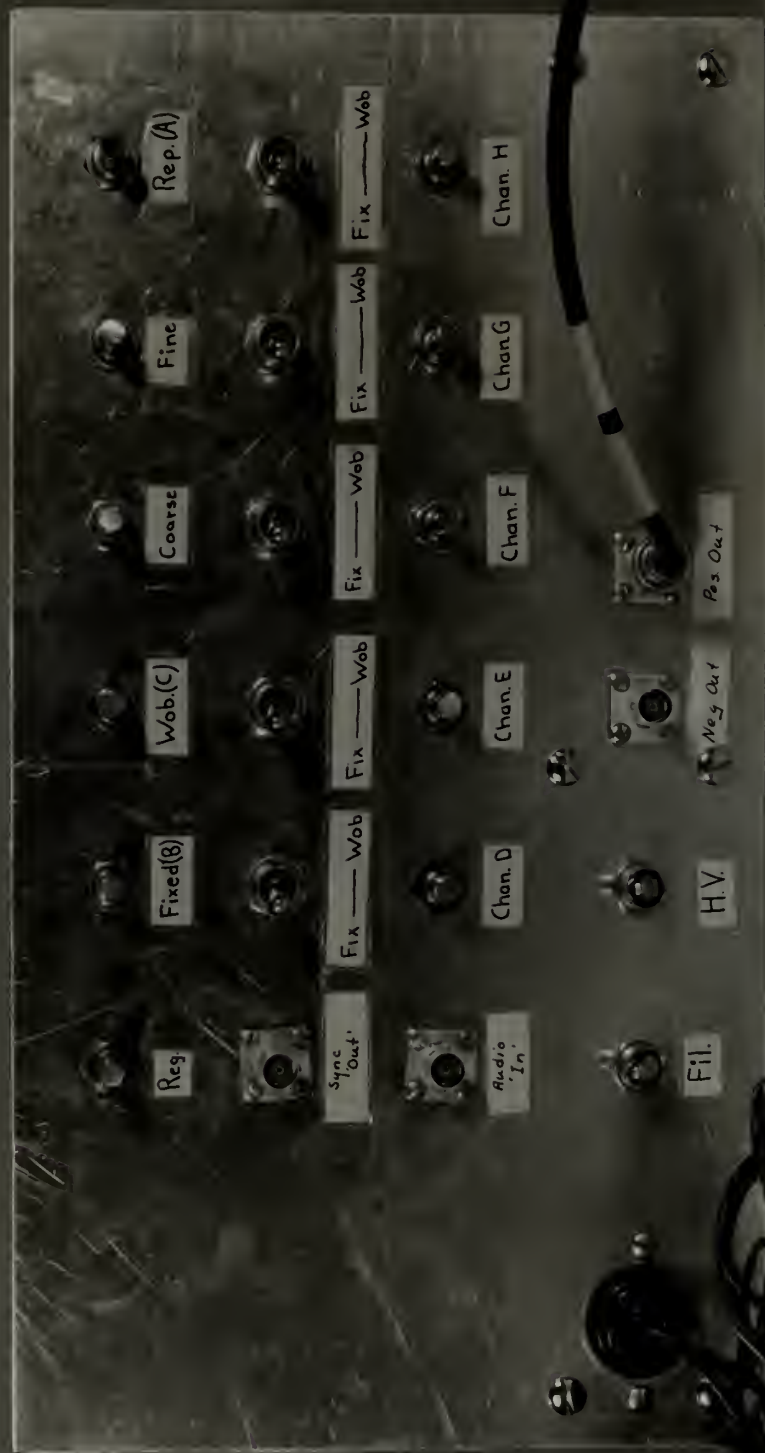
MAR 24 1952

CHANGE:

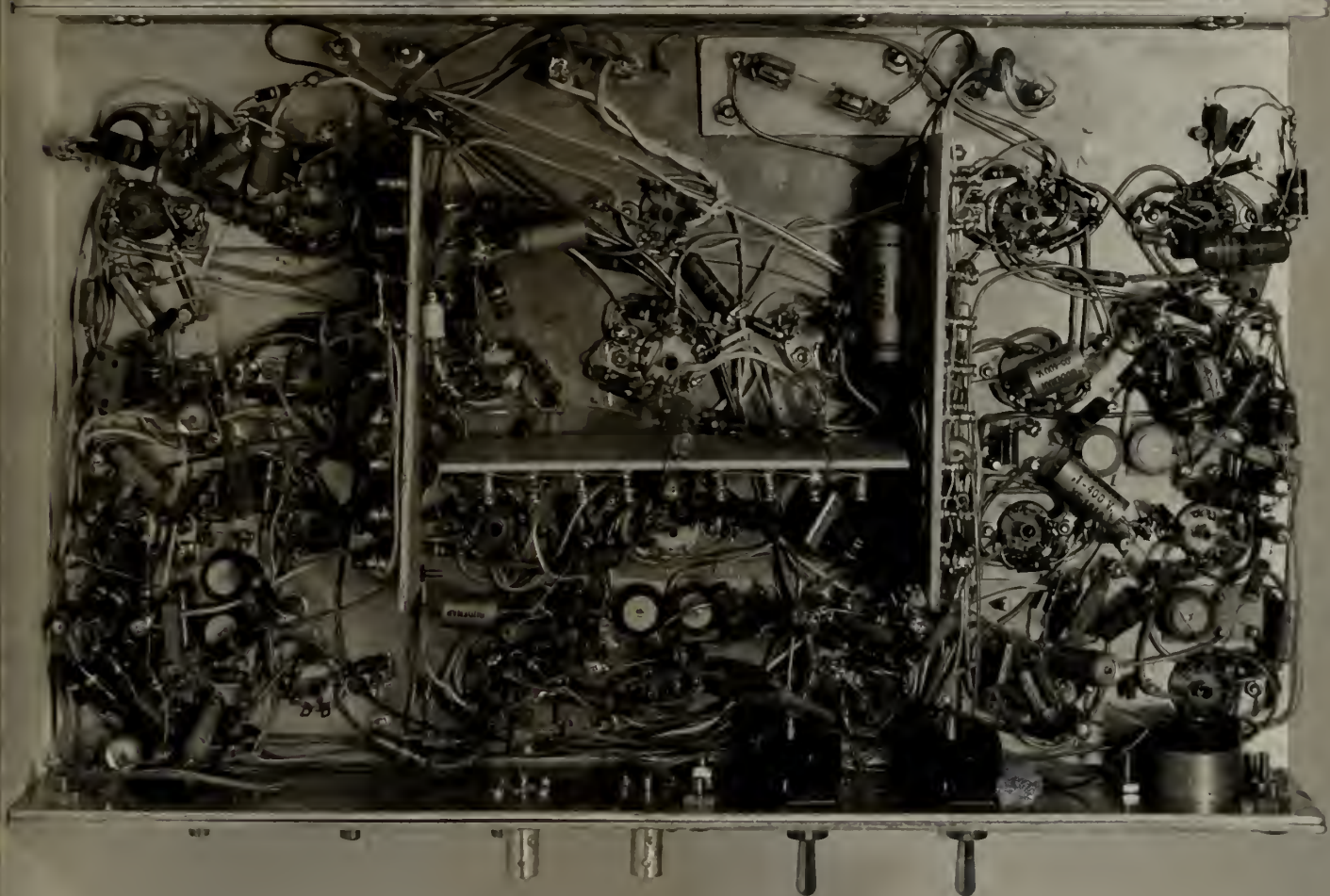
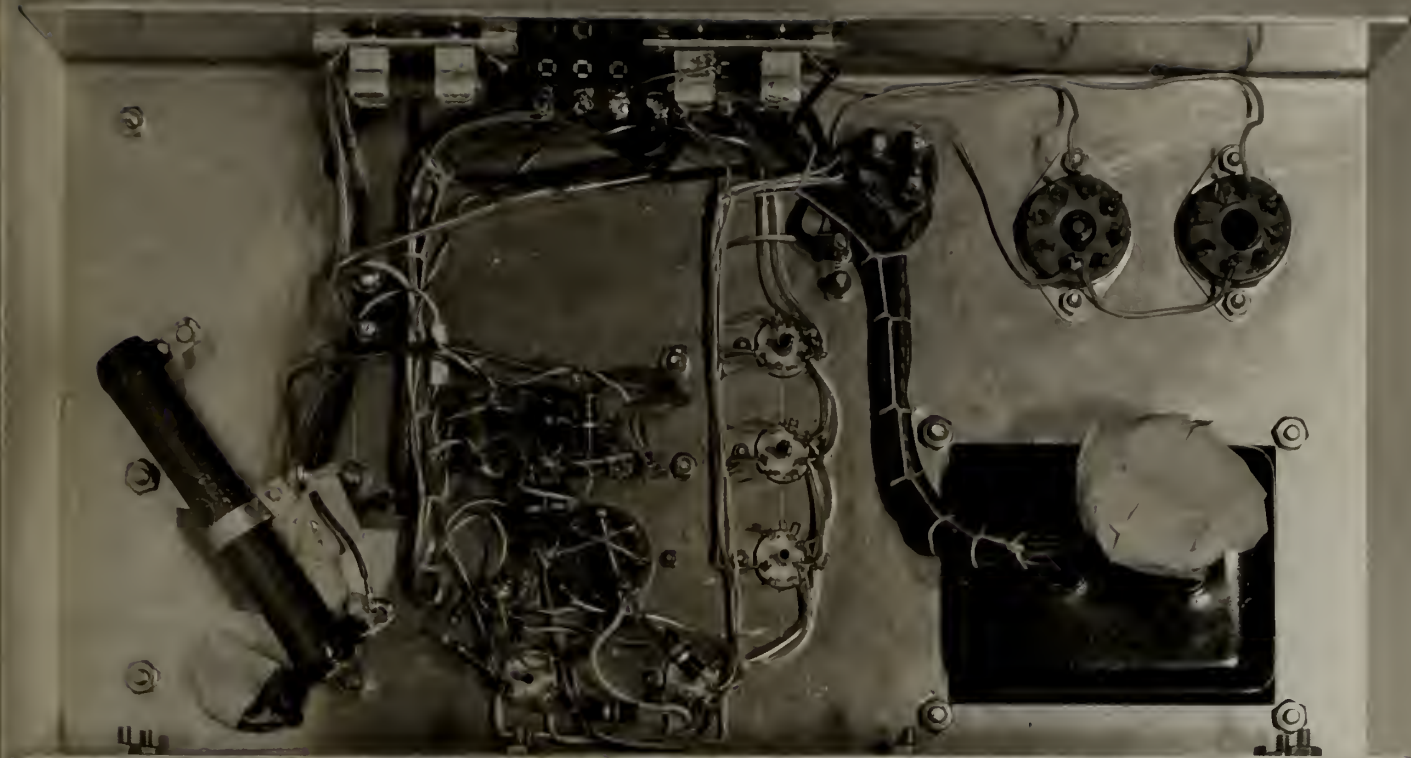
REQD	W NO	ITEM	NAME	FIN	ZONE	CIRCUIT SYMBOL
1			MELPAR, INC. ELECTRONICS			
			ALEXANDRIA, VIRGINIA			
			MODULATOR SCHEMATIC			
			DRAWN BY	ENGINEER	MATERIAL	
			CHECKER	PROJ ENGR	FINISH	
			APPROVED	SCALE	E 160	CHG.



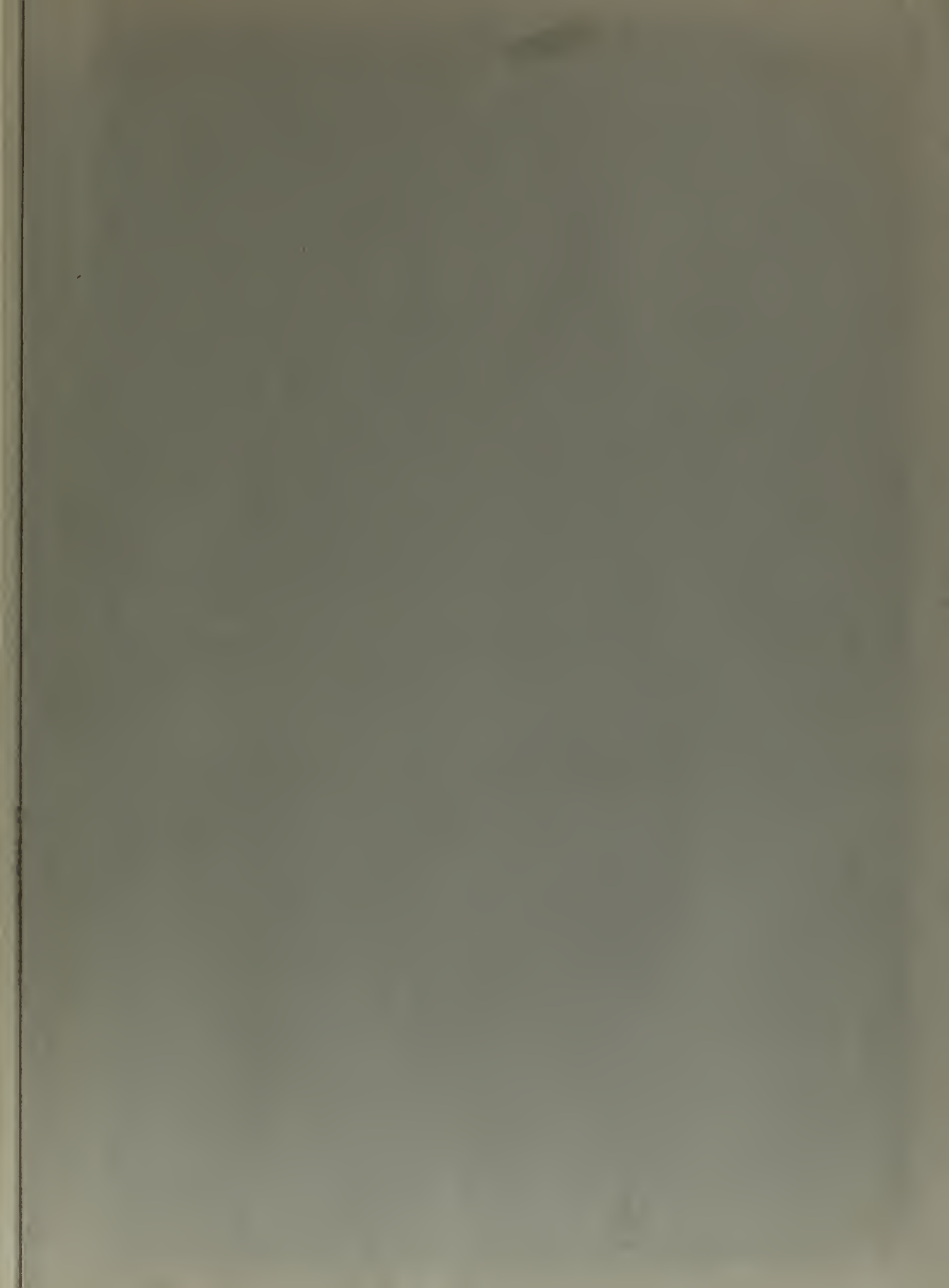
1153-3



1153-2







17 JUL 68

16547

17 JUL 68
R373

Rhinesmith 25028
A multiple micro-
pulse generator.

17 JUL 68

16547

17 JUL 68
R373

Rhinesmith 25023
A multiple micro-pulse
generator.

thesR373

A multiple micro-pulse generator.



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